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Pulverized Coal

IF any demonstration was needed of the keen interest of the marine fraternity in pulverized coal, it was amply furnished by the attendance at the recent session of the Society of Naval Architects and Marine Engineers at which the new fuel was discussed. Not only was the attendance larger than at any of these meetings which the writer has attended—and he has been present at a majority of them during the past 30 years—but the papers presented gave evidence of the most painstaking care in their preparation; and the discussion which followed their reading was of the greatest value, and indicated the close interest and attention with which engineers and shipping people are following the course of this latest development in marine engineering.

The papers themselves are reproduced elsewhere in this issue; the discussion brought out very clearly the serious attention which is being accorded to pulverized fuel, the advantages which may be expected to result from its adoption, and certain of the difficulties which may have to be met and overcome before it can generally be accepted as a proved and fully established success.

One fact, and a most important one, seems to have been definitely established, notwithstanding the experimental nature of the experience so far gained. This is that it is entirely possible to efficiently and completely burn pulverized coal of fair quality in the relatively restricted combustion spaces of marine boilers—both Scotch and watertube. Complete combustion is secured with a flame extending from 5 to 7 feet from the burner, and without direct impingement upon the sides of a 42-inch corrugated furnace. This first and vital part of the problem has evidently been completely and satisfactorily solved.

The feeding of the pulverized fuel to the burners is apparently not viewed with quite the same degree of confidence as are the burners themselves; many difficultis have been met in this portion of the process, but the results obtained on the tests indicate that the "distributors" which have been devised successfully break up the stratification of air and fuel in the ducts leading to the burners and that the powdered coal is uniformly distributed through the air current which carries it into the furnace.

The pulverizer was the subject of considerable discussion. It was pointed out that, while with oil fuel not over 1 percent of the steam generated by the boiler is used to feed the burners, with pulverized fuel as much as 7½ percent may be required. As the major part of this steam is required to operate the pulverizer, the necessity of the latter's efficiency, and also that of the auxiliary power plant of the ship, at once becomes apparent. As fine pulverization seems essential to high boiler efficiency, the ball type of pulverizer gave—on the tests—somewhat better results than were obtained with mills of the impact or paddle type; but it was considered that the former, as at present constructed, is rather heavy and bulky for marine use. It is to be expected that both types of pulverizers will be improved, both in efficiency and suitability for ship use, as the result of more extended experience with them. In their present forms, the amount of power necessary to operate them seriously reduces the gain in economy which can be derived from the use of pulverized coal.

Considerable apprehension has been felt as to the operation of pulverized fuel plants where wide variations of power are taking place, as when maneuvering a ship into dock; it having been considered as quite probable that recourse to oil fuel might then be found necessary. The writer of one of the papers presented gave considerable attention to this phase of the problem. It is most satisfying to be able to note that subsequent to the writing of the papers the steamer *Mercer*, upon which an initial pulverized coal equipment has been installed, has been brought from Baltimore to New York and that in maneuvering this ship out of dock in Baltimore, and later in New York Harbor, only pulverized fuel was used and that its control was entirely satisfactory.

It has been quite generally believed that pulverization would make possible the use of low grade coal, otherwise unsuitable for ship use. This, apparently, is a mistaken idea; for, while such coal may be used, the low fusing point

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of its ash causes a deposit of slag on the furnaces and tubes which is difficult to handle and which eventually is likely to cause a complete shutdown. It is concluded that a coal must be used which has an ash with a fusing point higher than the normal furnace temperature.

Altogether, a very good case for powdered fuel has been made out, for while certain difficulties attendant upon its use are evident, they are far outweighed by its numerous and very obvious advantages. It seems altogether probable that it will be extensively adopted upon commercial vessels in the near future, and that extended practical experience with it will bring about a successful disposal of most of the difficulties which at present remain unsolved.

New German Hull Forms

THE belief that "U frames forward and V frames aft" give, in general, the best hull form for propeller driven vessels has prevailed for so many years that the announcement of the development of a radically different type of underwater body, resulting in a very material decrease in resistance, comes as something of a shock.

While it is, of course, well understood that modification of form may give improved results, in individual instances, the type of lines which are, broadly speaking, considered "good" is rarely departed from to any very material extent, and the resulting increase or decrease in resistance, while often considerable in itself, is relatively small.

It is then, to put it mildly, very interesting to learn that a new hull form has been developed which according to a recent article in the Liverpool *Journal of Commerce,* is credited with a saving in engine power of from 11 to 25 percent. This new type of lines which the Germans, with characteristic energy, have very thoroughly investigated and are now putting to practical test, is really not new at all, having been invented some 20 years ago by Herr Maier, an Austrian engineer. Preparations were underway to put the invention to actual test in a full-sized ship, when the advent of the war caused a cessation of the work. Recently, however, the development has again been taken up, and an exhaustive series of tests of the new ship form has been conducted at the Hamburg Tank by Dr. Kempf. The following table, taken from the article previously referred to, gives a general idea of the results obtained with models of widely different types of vessels:

Type of Vessel	Displacement in Tons	Speed in Knots	Saving in Engine Power
Trawler	573	10	18.0
Small passenger vessel	285	22	25.0
Small freighter	4,467	10	16.7
Large freighter	18,320	14	15.5
Large transatlantic liner ..	46,500	27	11.0

These results are sufficiently startling to make a further study of the Maier form a matter of compelling interest. While the description at hand is not entirely clear, it appears that the new lines show a parallel middle body of approximately one-third of the over-all length. In the absence of other information, it may be assumed that the transverse section of this part of the vessel approaches the normal; otherwise, it is somewhat difficult to see how sufficient displacement could be had at any reasonable or practical draft of water. The frames in the end thirds, both forward and aft, are of distinct V or triangular section. An even more radical departure from present accepted practice is a sharp rise of keel above the base line for a full third of the vessel's length both forward and aft.

It is claimed that these lines reduce both frictional and eddy-making resistance and that the long, rising bow tends to ride over rather than force its way through the water, thus making a further reduction in the power necessary to drive the ship. These contentions seem to be borne out by the results quoted, and it is further stated that a very considerable advantage lies on the side of the new lines, when being driven into a head sea. In this connection, it is stated that two models of a large transatlantic liner were towed side by side in the tank, a distance of 13 feet between them. One model was of normal form, and the other had Maier lines. The latter proved to have much the shorter pitching period and, when towed at high speeds through rough water, was much drier and altogether made "better weather" of it. It is further claimed that the Maier model showed superior stability conditions, and that it offers greater deck area and more "straight line" spaces, suitable for passenger accommodations, than the normal form.

It would seem that such a radical departure from existing and proved practice could hardly be safely adopted on a large scale, on the evidence of model experiments alone; actual experience at sea would appear essential, but the Germans are apparently convinced and already several vessels, two of them of large size, are being constructed on the new principle. At least this shows the willingness of the Germans to undertake even radical ventures, when they give promise of commercial success, and also the close relation and mutual confidence which exists between their shipowners and technical men.

While detailed comment and intelligent criticism cannot be made in the absence of more complete knowledge, regarding the new hull form, one may perhaps be pardoned in speculating a little upon the basis of the present rather meager information. A first question arises as to the effect of the rising keel line upon steering in a seaway. Cutting away of the forefoot and also of the deadwood aft, increases maneuvering ability but increases the difficulty of holding a true course, particularly in rough water. It is at least problematical how a large liner with abruptly rising keel line will behave when driving into a North Atlantic winter gale and sea. With further reference to the rising keel line and V shaped after sections, one wonders how the rudders, to say nothing of the multiple propellers and shafting of the modern high powered liner, are to be efficiently supported and just what effect the new hull form may have on propeller action, as well as upon steering.

While greater deck area is reported as one advantage of the new type, it would seem that this must apply to upper decks alone, for with the V shaped frames the lower decks must be reduced rather than increased. In this connection, it would also appear that cargo space would be restricted and

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stowage more difficult than with vessels of the ordinary form.

It is rather difficult to credit the report that the new high speed North German Lloyd ships are to be modelled on the Maier system; it would seem out of the question to stake such an undertaking as the building of a great liner upon a principle so far without practical proof or demonstration. But while it may be unlikely that these great vessels will show any such radical departure from existing practice as the Maier hull form, there is evidently enough tonnage underway in which the latter will be used to give it a thorough trial and to conclusively demonstrate what advantages may be derived from its use. The results obtained with these vessels will certainly be awaited with the greatest interest by everyone concerned with ships and shipbuilding.

Lloyd's Annual Report

OF the many and varied annual reports and compilations of statistics which come into his hands, there is no other containing more intensely interesting and such widespread information for the shipbuilder as the report of Lloyd's Register of Shipping.

The report for the year ending on July 1, 1927, is no exception to the general rule, insofar as the amount of information it contains is concerned; and, in addition, while we in this country may not be able to extract much of direct comfort to ourselves from the various statistics, it is at least satisfying to find that they indicate fairly clearly that the long hoped for corner has finally been turned, and that the world's shipbuilding, as a whole, is finally and definitely on an upward trend. Even we may gather some small comfort from the fact that the largest motorship which has been built to the society's classification during the past year is an American vessel—the *Gulfpride,* of 12,510 gross tons. The following facts which the statistics set forth are of general interest:

As of July 1, 1927, there were over 29,500,000 gross tons of shipping afloat which were classed in Lloyd's Register. The total of vessels afloat and under construction to the society's classification was over 31,500,000 gross tons. The figures are too large to grasp, but at least give an idea of the enormous business conducted by this oldest of classification societies.

Turning to the more detailed and technical sections of the report, it is of interest to note that 20 vessels classed with the society were constructed on the Isherwood system of longitudinal framing, 17 out of the 20 being oil tankers, while 5 tankers have been built and 24 are in process of construction in which the Isherwood bracketless system of construction is used.

The number and tonnage of oil tankers in service has steadily increased from a total of just over 2,929,000 gross tons in 1919 to 5,915,000 tons in 1927. A considerable part of this increase was due to the building of the enormous American tanker fleet during and just after the war. We still have the largest tonnage of commercial tank vessels of any country, but with the rapid increase in the foreign tonnage of this class of ship, particularly of motor tankers, it seems evident that we shall soon have to bestir ourselves if this, our only field of tonnage leadership, is to be retained.

It is of further interest to note that four American lake steamers, totaling 27,269 gross tons, have been classed with Lloyd's during the past year. Thirty years ago the classing of an American vessel with Lloyd's Register was a difficult and wearisome matter. All plans had to be sent to London for approval, and as the technical committee there had little understanding of, and apparently little sympathy with, our peculiar needs and requirements, adjustments were slow and the uncompromising "take it or leave it" spirit with which plans were returned to the shipbuilders for correction and amendment more often than not led to an entire abandonment of the attempt to obtain the foreign classification.

Now, happily, all this has been changed and if any proof were needed of the broadened view of the London society and its evident desire to cooperate with American shipbuilders and shipowners, it is furnished by its classification of ships of such special type as the lake bulk cargo vessels.

To follow on with the report: 15 vessels have been equipped with steam turbines, 2 with double reduction and 13 with single reduction gearing. Of the latter, 10 of over 10,000 tons each were equipped with single reduction gears, which seems to indicate that the use of the turbine, at least so far as British ships are concerned, is still mainly confined to vessels of relatively high power and speed. A large proportion of the emergency cargo tonnage built during and following the war was equipped with high speed steam turbines and double reduction gearing, but statistics indicate that this class of vessel is now being provided in a majority of cases with internal combustion machinery, and in the remainder with reciprocating steam engines.

Turning to the use of oil fuel, the report shows that while in 1914 the total tonnage equipped for its use was 1,310,000 gross tons, in July, 1927, the figures had grown to over 18,481,000 tons; though attention is called to the fact that this includes ships equipped to burn either coal or oil, and is not confined to those actually using the liquid fuel.

During the past year, 92 motorships of approximately 393,000 gross tons have been classed by the society, 12 of them being of over 8,000 tons each. On July 1 the Register Book recorded 2,552 motor-driven vessels of 100 gross tons and over, the total tonnage of motorships reaching the impressive figure of 4,270,824. While two-thirds of the total number of motorships is comprised of vessels of less than 1,000 gross tons, there are 153 of from 6,000 to 8,000 tons, and 88 of over 8,000 tons each.

A most interesting table is the one in which the tonnage of ships propelled by various types of machinery is set forth. Disregarding the abnormal period following the war, the following figures indicate the trend in types of propelling machinery:

Of the new tonnage constructed under Lloyd's survey, in 1923-1924, approximately 610,800 tons were propelled by reciprocating steam engines, 99,400 tons by turbines, and 164,000 tons by oil engines. Of the new ships recorded as built under survey for 1926-1927, 405,280 tons have reciprocating steam engines; 168,557 tons, geared turbines;

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and 393,225 tons, oil engines. As the total tonnage classed in each of the two periods is approximately the same, the variations in the individual figures are most illuminating. It may further be noted that of the total for 1923-1924, approximately 468,000 tons used coal alone for fuel, while 406,000 tons, steamers and motorships combined, used oil. In 1926-1927, 298,000 tons used coal and 669,000 tons used oil for fuel. One cannot but wonder how far the introduction of pulverized coal may affect this ratio.

In the face of the preceding figures, it must not be forgotten that by far the larger part of commercial tonnage now afloat is still propelled by steam and uses coal for fuel. Of the total of 63,267,302 gross tons of power propelled vessels of 100 tons and over, recorded in the Register Book on July 1, 1927, 49,767,495 tons had steam engines; 9,228,983 tons had steam turbines, and 4,270,824 had internal combustion machinery; while 64 percent of the total used coal alone for fuel. Coal and steam still have a long lead—how long will they retain it?

The Naval Architects' Meeting

THE recent meeting of the Society of Naval Architects and Marine Engineers was one of the best attended and certainly one of the most interesting that the society has held during the 34 years of its existence. The innovation of having the papers of general interest read on the first day and confining the second day's sessions entirely to papers on pulverized coal and Diesel engines, two special and, at the present time, particularly live topics, was a most happy one and met with a response which must have been most gratifying to its originator.

The first day's papers covered a wide range of subjects. The strength of ships was intimately dealt with in the first two, in which studies of actual load and launching stresses and deflections in steel car floats were described and an exhaustive treatment of the strength of superstructures on large vessels and the much discussed utility of expansion joints was given. In the present "state of the art" the determination of the structural strength of ships is very largely a matter of comparison; actual measurements of stress and deflection, even when confined to car floats, form a valuable contribution to our knowledge of the subject. The remaining first day's papers were concerned with a variety of topics; their titles sufficiently indicate their character—"The Submarine of Today," "What is Naval Aviation Doing," "Tank Steamer Fires and Explosions." The last mentioned, by Mr. Robert L. Hague of the Standard Oil Company of New Jersey was a particularly interesting contribution, coming as it did from the technical head of one of the world's largest owners and operators of oil tank vessels. It most clearly shows that "eternal vigilance" is the price of safety in the tank ship as well as of liberty of the nation. Captain McEntee's paper on model tests with adjustable blade propellers, while short, was very much to the point. In view of the enormous extent to which propellers of this type are used, it seems somewhat surprising that they have not long before the present time been the subject of model tank investigation. The tests indicate that such wheels should be designed with a low rather than a high pitch as adjustment in service appears generally to tend to increased rather than decreased pitch.

For several years the Diesel has had the floor as a representative of progressive marine engineering; that it must now share general interest and attention with the latest comer to the field of ship propulsion was rather strikingly demonstrated by the second day's meetings. There are a number of reasons for the very great interest which the development of pulverized fuel has aroused in shipping circles. The two most important ones doubtless are, first, the opportunity offered for increased economy in the use of the world's most abundant fuel, coal, and, second, the probability that the new fuel offers the cheapest method of increasing the operative efficiency of existing vessels.

While the two papers on pulverized coal burning had to do mainly with experimental work on shore and while it would, to say the least, be unwise to predict future developments without a background of some actual sea experience the fact that it is entirely practicable to efficiently burn pulverized coal in boilers of the marine type, both Scotch and watertube, appears to be conclusively demonstrated. That changes in details of equipment and methods of operation will come as the result of practical operation on board ship, there can be little doubt, but in the meantime it appears fairly certain that pulverized fuel as an important player in the "shipping game" has come to stay. Both of these papers represent an enormous amount of hard and conscientious work on the part of a great many people and Mr. Jefferson and Mr. Stillman are to be congratulated upon the clear and convincing manner in which they have presented the results of the work done under their direction.

The next four papers were confined to descriptions and tests of marine Diesels, ranging from the large double acting engine recently completed at New London which, by the way, is one of the finest pieces of engine construction which it has ever been the writer's privilege to see, to the equally outstanding high speed oil engine which Mr. Treiber has under construction at Camden. Captain Gatewood's paper, with its description of all of the various types of internal combustion machinery which have been fitted to Shipping Board vessels, may be considered as filling the gap between the two first mentioned, while "Diesel Engines for the Navy" gives another slant on the absorbing question of Diesel development.

The final paper deals with a most important factor in the Diesel problem. Necessarily of a highly technical character, Professor Lewis' work is so clearly put down that a mathematical training is by no means necessary to get at the underlying principles which he develops. Ship vibration, which with the introduction of the turbine was forced into a back seat, has come forward with renewed vigor and added complications as a result of the introduction of the Diesel. It is a difficult problem to deal with but Professor Lewis, while admitting that the present engines, in many instances, leave much to be desired as regards internal vibration and stray forces, evidently has confidence that in most cases they are quite susceptible of improvement and that the major difficulties at present in the way of reducing both engine and hull vibration will eventually be overcome.

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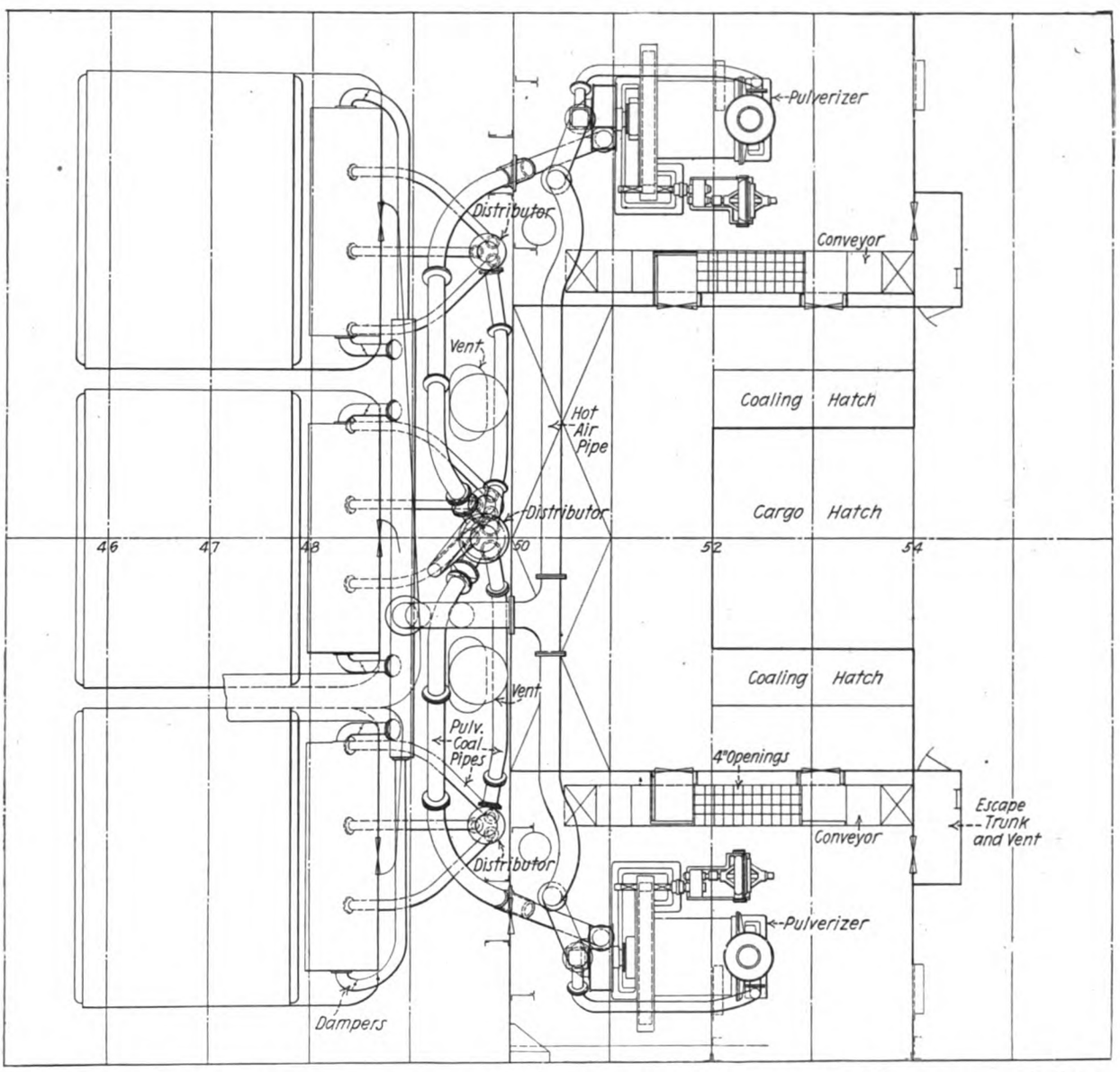
Pulverized Coal Equipment Installed on the Mercer

Tests being made to determine the practicability and economy of burning pulverized coal on a sea-going vessel

ON November 18 the Shipping Board steamship *Mercer,* which has recently been converted to a pulverized coal burner, sailed from New York for Antwerp with a staff of engineers on board to make a thorough test of the coal burning equipment on an overseas voyage. Previous to sailing from New York the *Mercer* made a successful voyage from Baltimore, Md., to New York burning pulverized coal and on November 15 and 16 two short trips, each of several hours' duration, were made outside New York harbor to demonstrate to naval architects, shipowners and marine engineers the practical working of this new equipment.

The installation of pulverized coal burning equipment on the *Mercer* is a continuation of the experimental work on the application of pulverized coal to Scotch boilers which has been carried out for the past two years by the United States Shipping Board and the United States Navy at the fuel oil testing plant at the Philadelphia Navy Yard. The object of these tests has been and is to develop an installation whereby the operating fuel costs of the vessels of the American merchant marine may be reduced.



Plan of boiler room and bunkers, showing location of pulverizers and coal conveyors and arrangement of piping and distributors

The vessel selected for this experiment was built for the Shipping Board in 1919 by the Federal Shipbuilding Company, Kearny, N. J. She is 395 feet 6 inches long between perpendiculars; 55 feet beam and 34 feet 11 inches depth with a deadweight carrying capacity on a 27-foot draft of 9,730 tons. Her gross tonnage is 6,219. The propelling machinery consists of 3 single ended 3-furnace Scotch

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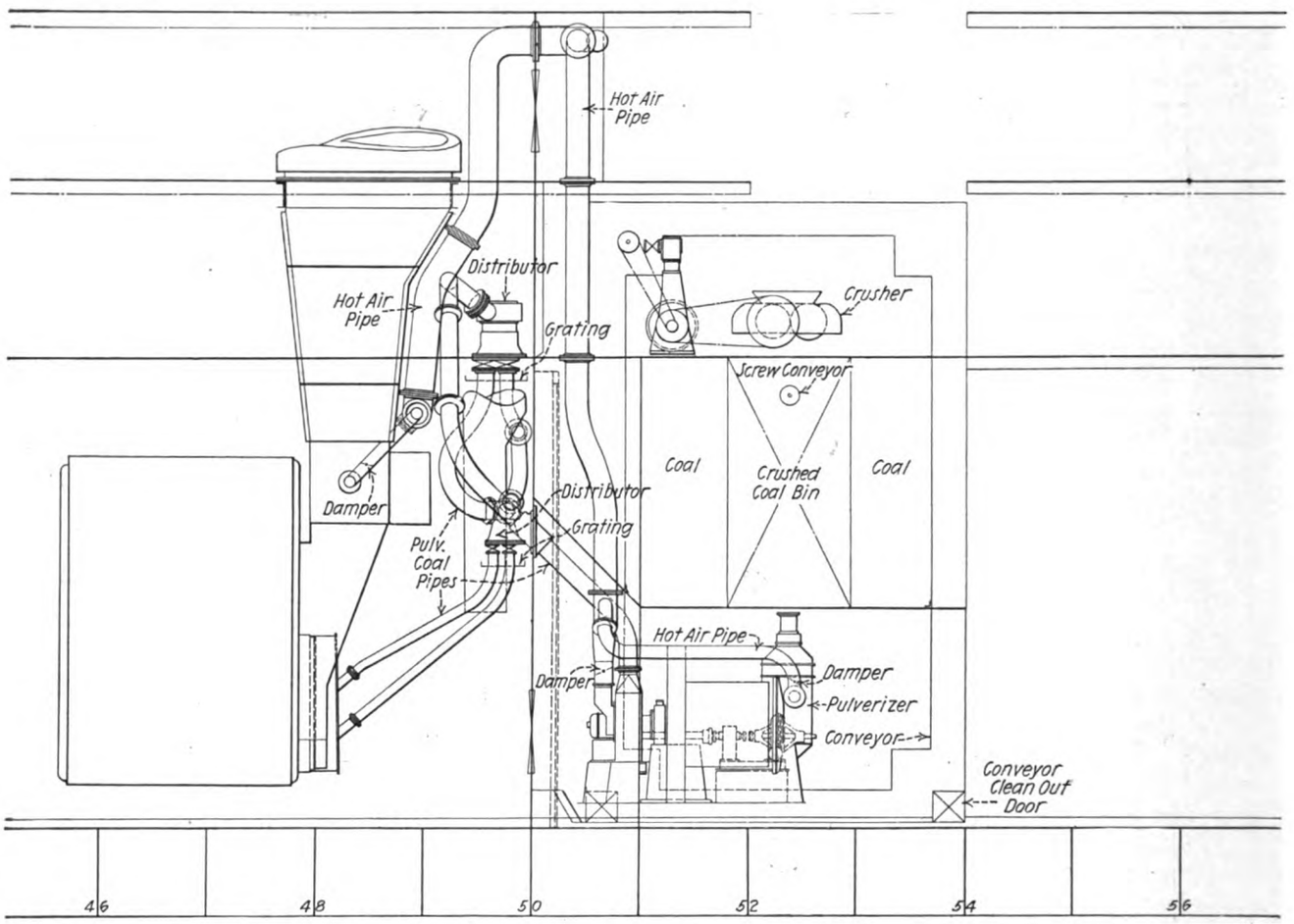
boilers which supply steam at 210 pounds per square inch to a General Electric geared turbine set of 2,500 shaft horsepower designed to drive the vessel at a speed of 10½ knots.

Bids for installing the pulverized coal equipment were received at the Shipping Board office in New York on August 31, the lowest bid being $36,498 submitted by the Maryland Dry Dock Company, Baltimore, Md. The pulverized coal burners were furnished by the Peabody Engineering Corporation of New York and are of the same type which gave such satisfactory results in the tests at the Philadelphia Navy Yard. They are of the combined oil and pulverized coal type and consist of an involute casting having an annular slot through which issues the coal and carrier air in an infinite number of jets each cutting another infinite number of jets and so setting up a turbulence which is augmented by a whirl motion given by the balance of the air needed for combustion. The combination of high turbulence with a large percentage of super-fines in the coal have made practical the use of pulverized fuel in the small furnace of a Scotch boiler.

The pulverizers are ball type slow speed mills furnished by the Kennedy-Van Saun Engineering and Manufacturing Company of New York. As shown by the plans, two pulverizers are installed in separate compartments, one on each side of the vessel, forward of the boiler room bulkhead. Coal is taken through openings in the side of the bunkers at the level of the pulverizer room floor where it is passed through a 4-inch mesh to endless chain bucket conveyors which have horizontal runs approximately 12 feet long and vertical lifts and returns approximately 25 feet high. These conveyors were furnished by the Link Belt Company of Philadelphia.

The coal after being reduced to a maximum 4-inch size in the pulverizer rooms is carried by the conveyors to crusher rooms on the deck above where it is discharged into single roll crushers built by the Jeffries Crusher Company where it is reduced to a maximum 1¼-inch size and is then discharged into daily supply or "ready" bins above the pulverizer rooms on each side of the vessel. From the daily supply bins the coal is fed by gravity to the pulverizers. Both the conveyor systems and the mills are driven by Sturtevant high speed single cylinder engines.

The pulverized coal is drawn from the pulverizer by a fan located on the after end of the mill. This fan, which is a part of the pulverizer equipment, discharges the pulverized coal with its carrier air into a series of distributors which split the current up into streams for the various boilers and in turn for the various burners of the individual boilers. The coal with the carrier air then enters the turbulent burners where it is supplied with additional air for combustion.



Longitudinal section through boiler room and bunkers, showing location of pulverizers and crushers and arrangement of piping and conveyors

Run-of-mine bituminous fuel is sued. The bunkering for the trial runs was made with coal supplied by W. A. Marshall, mined by the Lincoln Coal Company at Mine No. 1, Nanty Glo, Cambria County, Pa. The bunkers are so arranged as to have a natural run toward the discharge doors located in both the port and starboard pulverizer rooms.

On the voyage from Baltimore to New York and also on

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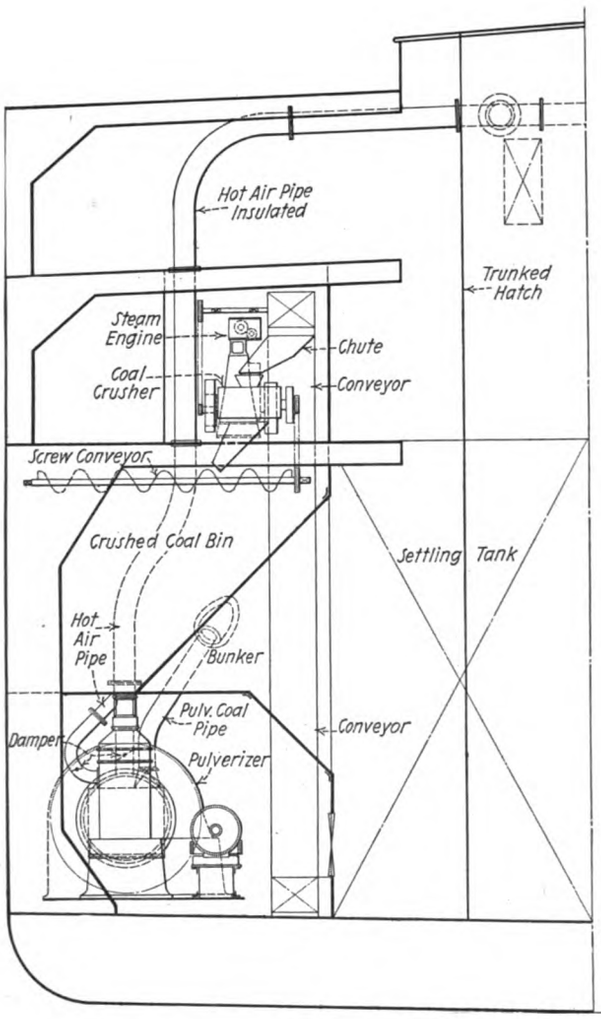
the demonstration runs in New York harbor the vessel was operated entirely with pulverized coal showing that a high degree of flexibility has been obtained with this equipment both for maneuvering and docking the vessel. At present no figures are available showing the actual fuel consumption of the propelling machinery or steam consumption of the auxiliaries with this particular installation, but it is expected that as soon as the vessel has completed her voyage across the Atlantic reliable data will be available. It is interesting to note, however, that with pulverized coal it is necessary to use only two of the three boilers on this ship to obtain full power. It is also of interest to note that it is necessary to run the crushers for only one hour per day to fill the daily supply bunkers.

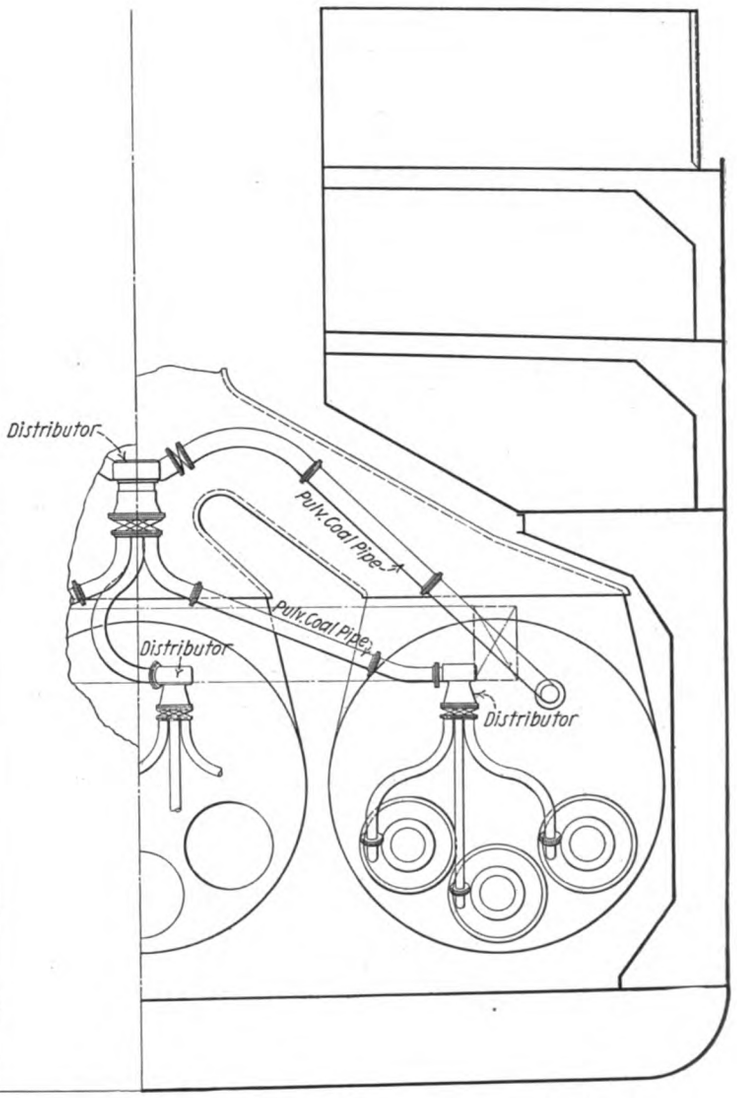
The pulverizers are operated at a constant speed of about 34 revolutions per minute. When maneuvering, the fires are controlled by regulating the amount of coal supplied to the pulverizers, which is accomplished by a motor operating two knives that scrape off the desired amount of coal from a flat disk at the bottom of the hopper leading to the pulverizer.

After the pulverized coal equipment was installed on the vessel, a full power dock trial was run on November 2 at the yards of the Maryland Dry Dock Company, using pulverized coal. The vessel then went on port load, still burning pulverized fuel, until 3 p.m., November 4, when she sailed for New York arriving there at 8 a.m. on November 6. The entire voyage, including maneuvering at both the port of departure and port of arrival, was made with pulverized fuel.

The installation was made under the supervision of C. J. Jefferson, head of the Fuel Conservation Section of the United States Shipping Board; Commander J. S. Evans, U. S. N.; R. A. North; C. H. Jack; E. L. Johnson and W. Richards. The engineers of the *Mercer* are C. J. Pierce, chief; J. C. McLean, first assistant; V. Perkins, second assistant, and D. R. Whitchurst, third asssistant.



Section through pulverizer room (at frame 53), looking aft



Section through boiler room (at bulkhead 50), looking aft

CURRENT AMERICAN SHIPBUILDING.—On November 1, American shipyards were building, or under contract to build for private shipowners, 188 steel vessels of 212,958 gross tons compared with 187 steel vessels of 187,117 gross tons on October 1, according to the Bureau of Navigation, Department of Commerce. There were 56 wood vessels of 28,096 gross tons building or under contract to build for private shipowners during the same period compared with 58 wood vessels at 29,374 gross tons on October 1.

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Test of Pulverized Coal Applied to Scotch Boilers*

Results of 240-hour continuous service test at Philadelphia Navy Yard on three-furnace Scotch boiler equipped with Peabody pulverized coal burners

By Carl E. Jefferson† and Commander Joseph S. Evans, U. S. N.

THE Dieselization program, which has become so important a factor in ship operation, has stimulated the efforts of the advocates of steam power to such an extent that marked progress has been accomplished during the last few years in producing steam economies. These give promise of successfully challenging the lower fuel costs made possible by use of the internal combustion engine.

A distinct advantage in the way of fuel costs characteristic of the improved steam plant is that the steam plant can use solid as well as liquid or gaseous fuel, which makes possible the use of the cheaper and more abundant type of fuels, especially coal.

However, in using coal as a fuel the problem of obtaining satisfactory labor, together with the problem of maintaining uniform rates of evaporation, is introduced, and it becomes necessary to find a mechanical substitute for the difficult and arduous task of hand-firing.

Research

The Fuel Conservation Committee of the Merchant Fleet Corporation of the United States Shipping Board, to whom is intrusted the task of reducing the fuel costs of the American merchant marine, recognized the above-mentioned problem and the benefits which would accrue from a successful solution which would enable the vessels to use coal as a fuel, providing the labor question and the question of sustained efficient combustion could be solved. Therefore a survey was made of existing land power plants to determine what they had to offer as a solution.

The survey showed a growing tendency towards the use of pulverized coal, inasmuch as this method of combustion permitted the use of fuels which could not be handled in any other manner.

Captain C. A. McAllister, chairman of the Fuel Conservation Committee, who gave special attention to this study, became an ardent enthusiast of pulverized coal. His enthusiasm continued throughout the development work and has helped mightily, when seemingly unsurmountable difficulties have occurred during the progress of the work.

The growing tendency towards use of pulverized coal, as stated, was found to be the trend in shore plants. However, it was not possible to adopt the shore plant installation for use on shipboard. The boiler in the average pulverized-coal shore plant is fitted with a combustion chamber approximately eight times as large as that found in a marine boiler of the same horsepower, and when the Scotch marine boiler is considered, there is the added difficulty of a completely water-cooled furnace wherein the use of refractories to speed up combustion is prohibited, as the greater part of the work done in a Scotch boiler is effected by direct radiant heat in the furnace.

The Scotch Boiler

The Fuel Conservation Committee is chiefly concerned with effecting economies in the existing merchant marine fleet rather than with proposed future tonnage.

It, therefore, must primarily consider the application of pulverized fuel for use in the Scotch boiler, inasmuch as the majority of the cargo carriers in service today are fitted with this type of boiler. Moreover, the positive limitation of combustion space of the Scotch boiler apparently presented a greater difficulty in adopting pulverized fuel for marine purposes.

It was for these reasons that the committee decided to concentrate its efforts towards developing a pulverized fuel system which could be safely and efficiently used in a Scotch marine boiler.

The purpose of this paper is principally to give in a brief form a report of the 240-hour test of the system which was finally developed and which is now being installed in the 9,700-ton freighter S. S. *Mercer* in order to determine by actual operation the real merits of pulverized fuel when applied to existing types of cargo vessels fitted with Scotch boilers, but it is believed a very brief history of earlier runs is desirable.

The project was not entirely new to the committee, as in 1920 the Fleet Corporation, during the Scotch boiler tests conducted by the United States Shipping Board in conjunction with the Bureau of Mines, had attempted to utilize the conventional streamline type of pulverized coal burner but with very meager results, as the maximum rate of combustion that could be maintained was 2.5 pounds of coal per cubic foot of furnace volume, or a maximum heat release of 32,000 British thermal units per hour per cubic foot of furnace volume.

In addition to the limited rate of combustion, the boiler efficiencies were far from satisfactory, as the combined air heater, superheater and boiler efficiency obtained was only 54 percent.

Between 1920 and 1925, however, considerable development had been made in pulverized coal installations. Some very definite facts had been established which at the earlier date were hardly even matters of conjecture. Chief among these facts was the effect of flame turbulence and of superfines in the coal on speeding-up rate of flame propagation.

These facts, coupled with the use of preheated air, indicated that, instead of the 20 to 25-foot flame travel necessary when using the stream-line burner and only ordinary fineness of coal, it would be possible to effect the same completeness of combustion within 8 to 10 feet of flame travel.

Plan of Tests

The Fuel Conservation Committee, having decided that the problem of developing a marine pulverized fuel plant was subject to solution, must needs determine the plan of attack.

This plan must include a considerable amount of test work along the line of development and adaption rather than pure research. It was also necessary that the tests be conducted by an unprejudiced, although sympathetic group of engineers, under as near sea-going conditions as possible. To this end, a request was made by the committee upon the Bureau of Engineering of the U. S. Navy, that they cooperate with the United States Shipping Board in this development work.

The Bureau of Engineering agreed to do this, and the

* Paper read at the thirty-fifth general meeting of the Society of Naval Architects and Marine Engineers, New York, November 11, 1927.

† Head, Fuel Conservation Section, United States Shipping Board.

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facilities of the Fuel Oil Test Plant at the Philadelphia Navy Yard were offered for this purpose.

TESTS

The initial installation made at the test plant consisted of a Fuller-Bonnot unit mill and Fuller-Lehigh well-type burners. The burner installation was not chosen so much from its characteristics of being a practicable marine type, for, as a matter of fact, it had several decided disadvantages from this point of view, chief of which was the multiplicity

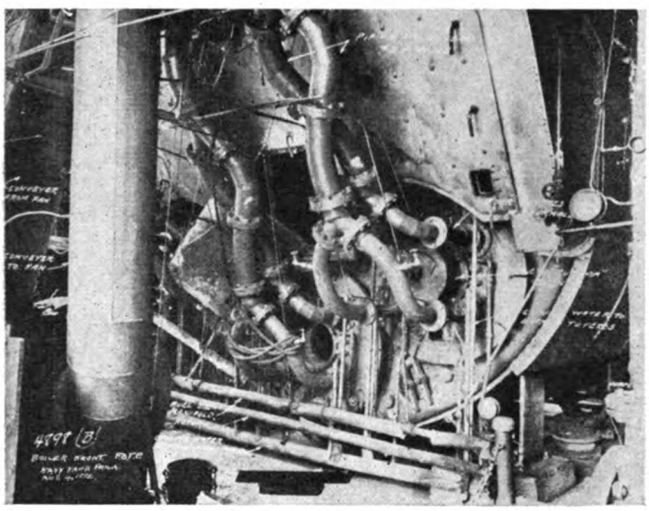

Fig. 1.—Scotch boiler fitted with Fuller-Lehigh well-type burners

of pipe work required, as may be seen from Fig. 1. But rather, it was chosen to determine the combustion conditions that could be obtained from a turbulent burner which was the direct antithesis of the stream-line burner.

The series of tests did not produce a practical sea-going installation, but they did demonstrate the feasibility of burning pulverized coal in the limited size Scotch boiler furnace. A combustion rate as high as 6.19 pounds per cubic foot of furnace volume was maintained for limited periods of from two to six hours with a heat release as high as 88,330 British thermal units, and a boiler efficiency of 68.7 percent was obtained for eight-hour test periods. It is to be noted that this boiler was not equipped with either air heater or superheaters.

The principal reasons for the failure to obtain continuous satisfactory service was the uneven distribution of fuel to the twelve burner nozzles and lack of proper control over the air pressures. This type of burner employed the entire supply of air necessary for combustion as primary or carrier air, and, as the pulverizer was an air-swept mill, any attempt to regulate the air supply affected both the turbulence and the fineness of product from the mill.

As both the manufacturers of the equipment and the test plant personnel were convinced that radical changes would be necessary to effect satisfactory continuous combustion, as well as to produce a type of installation that could be used on shipboard, this equipment was withdrawn from test for further research by the manufacturers.

In the meantime, the Peabody Engineering Corporation had been experimenting with a burner at one of the large power plants, and as this burner appeared to have the characteristics which made possible the peak performances of the above-mentioned installation, and as it was also so designed as to make it suitable for marine use, it was selected for the next series of tests. The mill used on the second series was a high-speed paddle type.

On this series, with comparatively low volatile coal and at moderate combustion rates, fairly satisfactory performances were obtained. The test runs of this series were of comparatively short duration, being made chiefly for the purpose of determining the performance of the burner rather than the complete installation.

The tests covered a range from 33,500 British thermal units per cubic foot of furnace volume up to 52,000 British thermal units per cubic foot of furnace volume. The boiler efficiencies obtained on two- to four-hour periods were approximately from 71 to 78 percent.

It was found in this series that, with the particular pulverizer installed, with a change in the quality of coal and in the capacity demand rate, there was a considerable variance in the fineness of grind obtained, and, as the manufacturers desired to withdraw their mill from the tests until they had completed further development work on it at their own plant, it was decided to again install a low-speed air-swept tube mill.

The mill selected for this purpose was the Kennedy air-swept tube mill manufactured by the Kennedy-Van Saun Engineering and Manufacturing Corporation. This mill has been used for the balance of the test work to date, including the 240-hour continuous service run.

The third series of tests consisted of a number of short runs over a period of about six weeks, during which various operating features were worked out, such as correct fan and distributor speeds, ball charge for mill, etc. During this period the operating technic of the personnel was also developed, and it was then felt that we were now ready to go ahead with a continuous service test which would demonstrate what could reasonably be expected in service.

THE 240-HOUR CONTINUOUS SERVICE TEST

This test started on July 27, 1927, and terminated August 6, 1927; during which tests, for forty-eight-hour periods

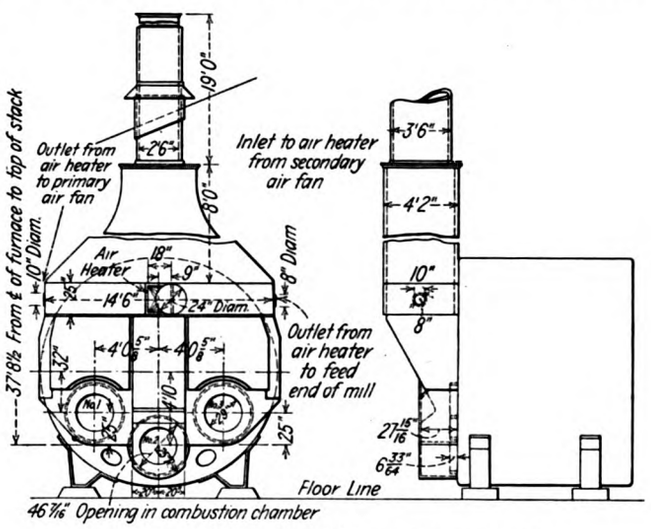

Fig. 2.—Boiler on which tests were made

following each other without interruption, combustion rates of 1,200, 1,400, 1,600, 1,800 and 2,000 pounds per hour were maintained.

It is desired at this point to acknowledge the assistance given by a number of manufacturing companies, coal companies, and individuals, whose aid made possible the accomplishment of this test: The Peabody Engineering Corporation, Kennedy-Van Saun Manufacturing and Engineering Corporation, both of whom not only supplied the major part of the equipment but who also furnished the services of their engineers; John Reid Company, which donated the secondary fan equipment; General Electric Company, which loaned certain electrical equipment; Bureau of Mines, which

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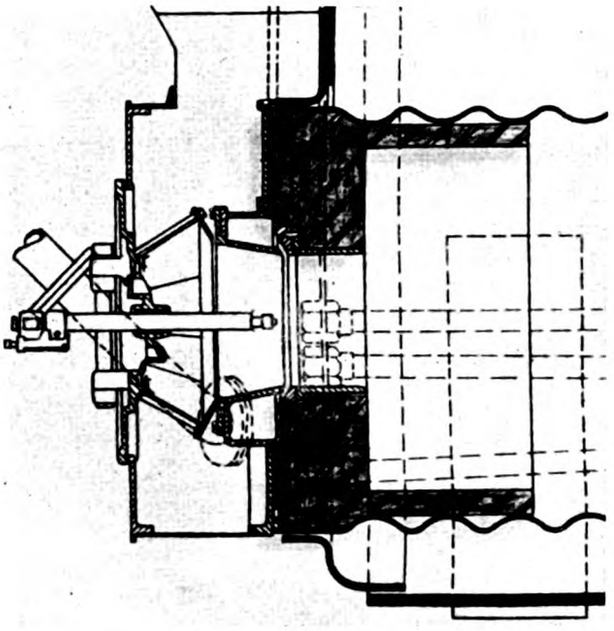

Fig. 3.—Section through Peabody combined fuel oil and pulverized coal burner installed in furnace of Scotch boiler

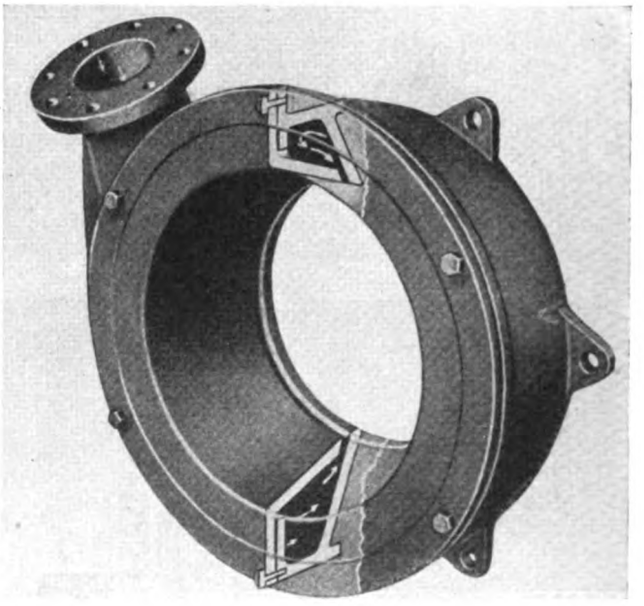

Fig. 4.—Coal box with air register removed

loaned measuring instruments; W. A. Marshall, who donated the greater part of the fuel used on the 240-hour test; Commercial Coal Company, which also donated fuel for this test; W. J. Faux, Keystone Coal Company, Weaver Coal Company, and the Coleman Coal Company, who have donated fuel used on the preliminary tests.

It is also desired to make special mention of the engineers who carried on the test work and calculation, especially Commander J. J. Broshek, Lieutenant Commander F. D. Kirtland, and Messrs. R. C. Brierly, W. Richards, E. L. Johnson, C. H. Jack, R. A. North, R. Vroom and C. Pyle.

BOILER

The boiler used in this run, as in the preceding preliminary runs, was a single-ended Scotch marine boiler having three furnaces with separate combustion chambers. It had been previously in service on the S. S. *West Eagle* but was installed at the Fuel Oil Testing Plant in 1923 for use in connection with other tests for the United States Shipping Board. Characteristics of this boiler are given in Table 1. Fig. 2 shows the general dimensions of the smoke boxes, uptake, air heater and stack. The air heater was not part of the original boiler but was built and installed by the Fuel Oil Testing Plant immediately prior to the test of the Peabody burners and the first mill used in conjunction with them.

A double front was also constructed on the boiler front for supplying preheated air to the burner air registers, as shown in Fig. 2. The latter were integral with burner front plates which were hinged to the exterior of the double front; the air registers thus could be swung outward toward the fireroom when the burners were not in use, to provide access to the furnaces. The furnaces were modified by installation of a ring of refractory 18 inches long, as shown on Fig. 3.

The only other modification was to provide three holes in the rear of the boiler, each hole being, as nearly as possible, in line with the center of each furnace. These holes were made by fitting three stay tubes through the rear head and rear sheets of the combustion chambers. These stay tubes replaced an equal number of staybolts and served not only as inspection holes for examining the appearance of the flame in the furnaces but also as entrances for piping for obtaining gas data.

BURNERS

The burners used were three Peabody combined fuel-oil and pulverized-coal burners as manufactured by the Peabody Engineering Corporation. Fig. 3, shows this burner complete, installed; Fig. 4, shows the coal box with the air register removed; and the burner front and, logitudinal elevation are shown, in section, in Fig. 5.

This burner, as stated above, is a combined oil and pulverized coal burner, but as this paper is concerned principally with the burning of pulverized coal, no description of the fuel-oil atomizer is considered necessary. It is sufficient to say that no difficulties were experienced with the burner while burning oil. The atomizer can be readily withdrawn when changing from oil to coal and can be put in position as easily when it is desired to burn oil.

The coal burner is composed of two principal parts, the air register and the coal "register" or coal box. The function of the air register is to regulate admission of such air (in addition to that air which carries the pulverized coal) as may be necessary for complete combustion, and also to cause such air to assume a rotary motion, so that, as this air meets the stream of carrier air and its contained coal from the coal "register," the entire volume of air and coal is given increased turbulence, principally by rotation.

Varying the opening of the air register is accomplished by means of a star wheel, on the front of the register, which actu-

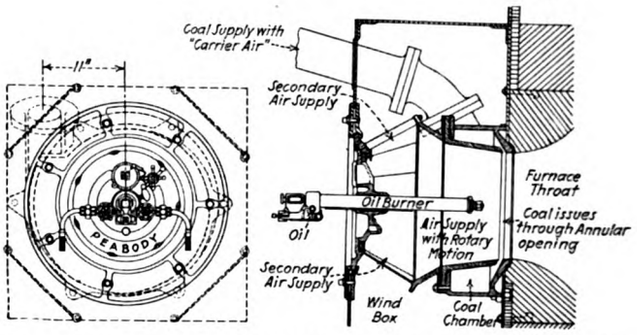

Fig. 5.—Peabody combined oil and pulverized coal burner

ates the register shutters by a rack and pinion device. An additional star wheel provides for locking the air register in any position.

The function of the "coal register" or coal distribution-box is to distribute the pulverized coal uniformly around the burner. This register consists of a hollow casting in the form of an involute of rectangular cross-section, having in its inner surface, near the furnace end, a slot through which the coal stream enters the throat of the burner. This slot is sloped slightly towards the furnace end of the burner, and this sloping, together with the involute shape of the casting, gives the entering coal and carrier air stream a forward rotary motion, which motion is augmented by the secondary air stream entering through and directed by the air register. Connection between the coal "register" and the coal feed line is made by means of a flanged pipe joint, the cross-section of the area through which the coal and carrier air stream passes gradually changing from circular at the flanged joint to rectangular along the involute.

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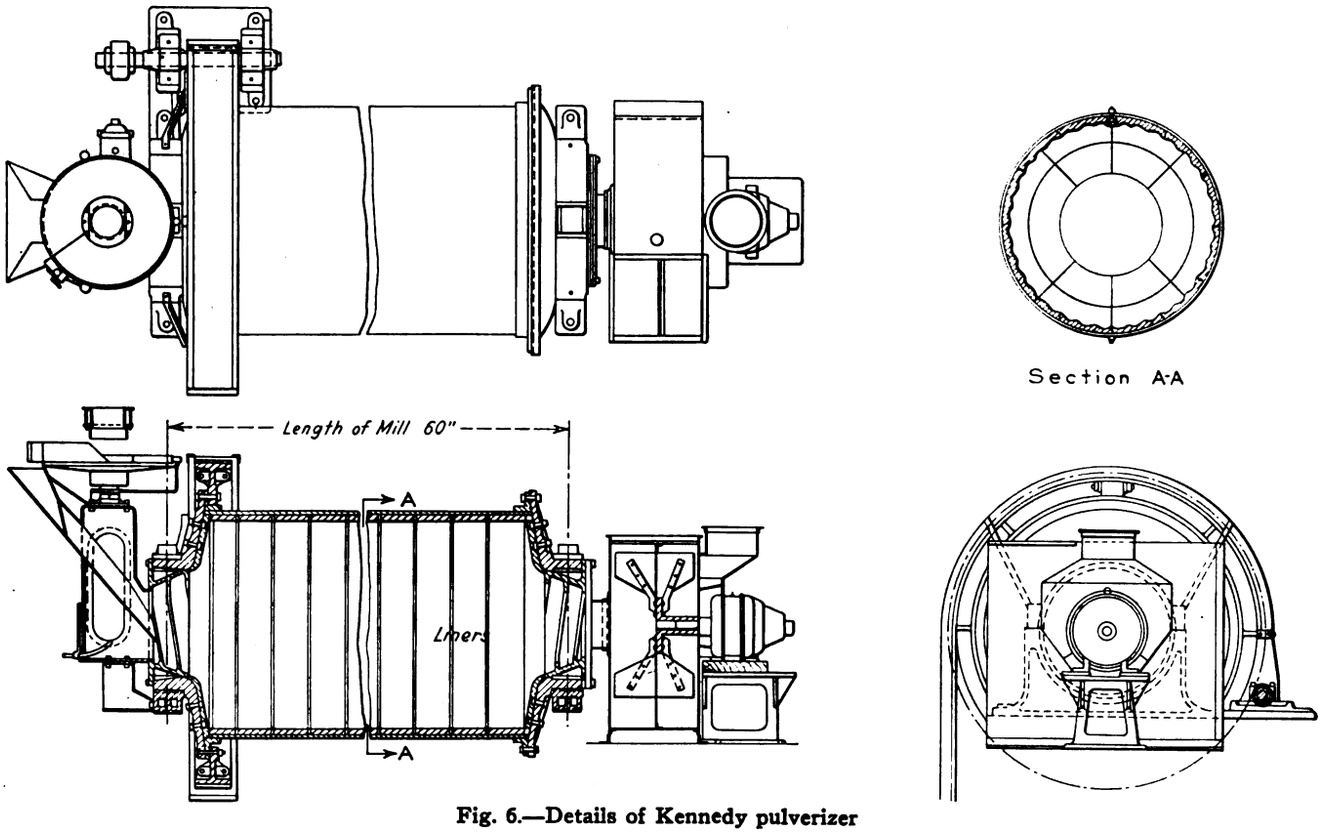

Fig. 6.—Details of Kennedy pulverizer

PULVERIZER

The pulverizer used was a Kennedy air-swept tube mill, manufactured by the Kennedy-Van Saun Manufacturing and Engineering Corporation. Fig. 6 shows an assembly view of this mill. The mill consists of two cylinders, the inner one of which is in sections which are secured to the outer, a layer of insulatnig material being inserted between the two in order to deaden noise. The exterior of the outer cylinder is covered with a layer of hair felt, wired in place, over which is secured a covering of cork linoleum ⅜ inch thick, secured by steel straps.

The sections of the inner cylinders are corrugated to assist the cascading of the ball charge.

The heads of the mill are bolted to the outer cylinder and carry hollow journals, the bore of each being machined to the form of a truncated cone with the larger diameter towards the interior of the mill. In the bore are machined three square screw threads, those at the feed end being of opposite hand to those at the discharge end, this construction being such that everything tends to feed into the mill and to prevent any of the ball charge or any large pieces of coal from working out of it.

The pulverizing medium is a charge of Herculite steel balls. On this run, the charge was 5,190 pounds. Any depletion due to wearing of the balls can be made up simply by feeding additional balls into the feed end of the mill either while it is in operation or at rest. This mill requires no magnetic separator for removing tramp metals as such metals can do no harm, and, if such do enter, simply add to the pulverizing charge.

The mill in this installation is driven by a steam turbine, manufactured by the Carling Turbine Blower Company through a Poole speed-reducing unit, pinion and herring-bone gear wheel, the latter being bolted to and around the flange which connects the outer cylinders to the discharge head of the mill.

The mill is equipped at the feed end with a feed hopper and feeder disk. The feed hopper is simply a conical-shaped bin which directs the entering coal stream on to the feeder disk. The feeder disk consists of a rotating circular steel plate, on the top surface of which the feed hopper delivers the coal centrally. The coal spreads over the feeder disk in a conical pile but is prevented from spilling off by a stationary sheet metal guard which rises a few inches above the level of the upper surface of the feeder disk. This guard does not extend entirely around the periphery of the disk but is cut away for about 30 degrees in order to give space for the feeder "knife." This "knife" is a metal arm or finger which extends from the casting which supports the feeder, over on top of the disk, its function being to scrape a portion of the coal continuously from the pile on the disk into the small chute which leads from the outer edge of the disk into the mill through the hollow feed and journal. The position of the knife, and therefore the amount of coal fed from the disk into the mill, is adjustable by means of a hand-wheel-operated worm which meshes with a semi-circular gear attached to the outboard end of the knife. During test it was discovered that this mechanism might "creep," thus changing the position of the knife, and therefore a set screw was fitted to prevent such creeping.

The speed of rotation of the feeder disk, and therefore the rate of feed to the mill, can also be varied, the disk being driven by a variable speed ½-horsepower motor. Further description of this motor and control panel is believed to be unnecessary.

The mill is equipped at the feed end with an air box which has two openings, one a connection to the preheated air pipe, Fig. 7, which furnishes air for sweeping the mill, and the other for inspection purposes or for adding to the pulverizing charge. This last mentioned opening is closed by a metal door, hinged at its upper edge, and provided at its lower edge with a hinged toothed sector, which sector can be engaged with the edge of the opening, so that the door may be held in any of several open positions in case it is desired to admit more air to the mill than can be admitted through the regular air connection.

The mill is equipped at the discharge end with a motor-driven fan, hereafter called the "primary air" fan. This fan, as furnished, was of the duplex type; that is, both the fan rotor and casing were divided into two parts, the rotor being divided from the hub to the outer edge by a steel plate to which the fan blades were riveted, and the casing was divided by a corresponding plate riveted to the wrapper plate of the casing, the latter plate being in the same plane as the former. The fan rotor is 25 inches in diameter and carries six sets of blades, the axial length of the blades on the mill end of the fan being 7 inches and those of the motor end of the fan 6 inches.

This fan takes suction through its center and discharges vertically upwards. That section of the fan adjacent to the mill takes its suction principally through the mill through the hollow journal on the discharge head. The fan casing on the mill end was, however, equipped with an air box surrounding the hollow journal. When the fan was first installed this air box was kept closed, but during the preliminary tests it was found necessary and desirable to furnish some air through this box, and, therefore, it was connected to a preheated air duct, and during the run covered by this paper this mill end of the primary fan took suction not only through the mill but also from this air duct, which was fitted with a damper for regulating the amount of air taken through this connection.

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Preliminary tests showed that satisfactory operation was not practicable when using the fan "duplex," and prior to beginning this run the suction to the motor end of this fan was blocked and this entire run was made with the fan operating "simplex." This fan was driven by a variable speed 5-horsepower motor, but no further description of the electrical equipment is considered necessary.

DISTRIBUTOR

Directly above the discharge from the primary fan and connected to such discharge by a short adapter duct was the "distributor." This consisted of three parts, the distributor body, distributor head, and the distributor rotor. The body is a cylindrical steel pipe, connected by a flanged joint at the bottom to the previously mentioned adapter duct, and by a similar joint at its upper end to the distributor head. This head is a casting, cylindrical at its lower end and divided in the upper part to give three equidistant equal area discharges. The rotor, which is motor-driven by a vertical motor placed over the distributor head and between the three discharge connections, as furnished by the Peabody Engineering Corporation, consisted of a four-bladed fan 11 inches in diameter and with blades 15 inches in length. This rotor was connected by a coupling to the shaft of the driving motor. It was found during the preliminary tests that this distributor did not function satisfactorily, and therefore a new rotor or fan was designed and built at the Fuel Oil Testing Plant, and this rotor was used during the run being described. The function of the distributor is, as the name implies, to distribute the carrier air and its contained pulverized coal evenly and equally to the three burners through the three discharge connections on the distributor head and the coal feed lines which connect the distributor head to the coal "registers" of the burners. These feed lines were made as nearly as possible of the same length in order to avoid inequalities of distribution, but exact equality of pressure drop through the three lines was not obtained, and therefore the amount of coal fed to all furnaces was not the same, as is clearly shown by the results from the different furnaces.

SECONDARY AIR FAN

The secondary air fan is a steam engine-driven blower as manufactured by the John Reid Company. This blower had a rotor approximately 48 inches in diameter, having twelve blades, the blades having an axial length of 18 inches. This fan had center suction and vertical upward discharge. The function of this fan was to draw air from the fireroom and discharge it through a sheet metal duct to the front center of the air heater. This duct, together with the connections from the air heater to the air entrance at the intake end of the mill and also to the air entrance at the discharge end of the mill, is shown in Fig. 7.

COAL

The major part of the coal used on the run was mined by the Lincoln Coal Company at its mine No. 1, Nanty Glo, Cambria County, Pa. It is known as Miller "B" seam, Nanty Glo basin, Pa., semi-bituminous, and was furnished by W. A. Marshall & Company. In fact this coal was used throughout the run except for the last 44½ hours, when coal furnished by the Commercial Coal Company at Commercial Colliery No. 5, Twin Rocks, Cambria County, Pa., was used. This was also Miller "B" seam coal from the Nanty Glo basin.

The coal was stored in an open bunker outside the fireroom, from which it was raised by a bucket conveyor to a "ready" bin or hopper. A metal screen was fitted on top of this bin and such large lumps of coal as had not been broken before being conveyed to the top of the bin were broken on the screen, so that no pieces of greater dimension than about 3 inches entered this hopper. The coal was fed from this hopper through a regulating sliding gate to the weighing box, where a 6-inch minute supply was weighed and passed to a screw conveyor which conveyed the coal to the feed hopper of the mill. Any coal that was accidentally spilled, after having been weighed, on the fireroom floor, was carefully swept up once or twice each watch and placed in the feed hopper of the mill.

Samples of coal for analysis were taken by removing a 300-cubic centimeter scoopful from the weighing box before each weighing. The coal thus removed was collected, the whole quantity for each watch was thoroughly mixed, and then quartered until a sample of suitable weight had been obtained. The sample was then placed in an air-tight can, marked and held for analysis at such time as convenient. Analyses were made by the Bureau of Mines and also by the Fuel Oil Testing Plant.

Samples of the pulverized coal for fineness tests were taken, once at the middle of each watch, from the duct connecting the discharge of the primary fan with the distributor. This duct was of rectangular cross section and was fitted with two sampling tubes of 1-inch inside diameter brass tubing, at right angles to each other, each fitted on its inner end with an elbow pointing counter to the direction of flow of the coal and carrier air in the duct. Each of the sampling tubes, which were arranged to slide through gland-packed stuffing boxes in the walls of the duct, was divided along its length into equal divisions, each division representing one-tenth of its total travel into the duct; and each was, when not in use, closed by a plug in its outer end.

A sample was collected by placing a bag similar to the bag of a vacuum cleaner over the outer end of the tube, removing the plug and collecting for one minute at each marked point on the tube length, the tube being moved entirely across the duct in ten minutes. The bag was then shifted to the other sampling tube and the duct traversed in a similar manner. This total sample was then quartered in the usual manner to obtain the final sample, which was then placed in an air-tight can, marked, and held for screening tests at such time as convenient.

The screening tests were made on a RO-TAP testing sieve shaker, using six screens and a receiver. These screens were of the following mesh: 50, 70, 100, 140, 200 and 300.

WATER

Raw water from the city mains was used throughout the run and was carefully weighed. The weighing equipment consists of two tanks, each having a capacity of 7,500 pounds, and each mounted on a platform scale. While one tank was being filled and weighed the other tank was being emptied into a constant level tank from which the feed pump took suction.

The feed pump used throughout the greater part of the run was a duplex reciprocating pump. Although this pump had been overhauled and new steam piston rings installed just prior to the run, it gave trouble at times, causing a few anxious moments. This pump delivered to the boiler through a feed heater equipped with thermometers on inlet and outlet.

GAS ANALYSIS

Samples of gas were taken with an Orsat apparatus from open-ended pipes passing through the rear casing of the uptake, drawing gas from the center of each smoke box just below the air heater.

Gas analyses were also made by a Ranarex indicating and recording meter. This meter was connected to three additional sampling tubes located in approximately the same place as those described above, except that the sampling tubes entered the smoke box through the front casing. The Ranarex equipment was so connected that indications and records from it concern only the center furnace, as the other sampling tubes were closed by valves at the meter end. Analyses by Orsat were taken hourly from each smoke box.

TEMPERATURES

Temperatures at the following points were taken hourly by thermo-couples with a Brown indicating pyrometer:

(*a*) Rear sheet of each combustion chamber.
(*b*) Air ducts, left and right, leading from air heater down to double front.
(*c*) Burner spaces in double front, between wing and center burners.
(*d*) Heated air duct at feeder end of mill.
(*e*) Heated air inlet to primary air fan.
(*f*) Duct between discharge from primary air fan and distributor.

A Leeds & Northrup six-point recording pyrometer recorded temperatures at three positions in the smoke box just under and above the air heater. These were so located that each pair, upper and lower, were in the path of the gases from one furnace and were near the open ends of the gas-sampling tubes.

AIR AND GAS PRESSURES

Air pressures or drafts were measured in inches of water on standard U-tubes at the following points:

Primary Air

(*a*) Heated air duct at feed end of mill; (*b*) discharge from primary air fan; (*c*) heated air duct at discharge end of mill; (*d*) each feeder pipe, just beyond the distributor; (*e*) each feeder pipe, close to coal "register."

Secondary Air

(*a*) In duct from fan discharge; (*b*) in double front, between wing and center burners.

Gas

(*a*) Each combustion chamber at peepholes; (*b*) smoke box (three positions) under air heater; (*c*) smoke box (three positions) above air heater.

CALORIMETER

A Babcock & Wilcox type throttling calorimeter was used on the steam line at the boiler. This was installed and calibrated in the standard manner.

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POWER CONSUMED BY MILL AND AUXILIARIES

The three motors used, coal feed, primary air fan and distributor, had watt-hour meters wired in their circuits so that the power requirements for these parts of the apparatus could be ascertained separately.

The mill proper being turbine driven, careful record of its speed (pinion) and the steam pressure was kept, and after completion of the run the pinion was disconnected from the gear, a Prony-brake equipment was installed, and the power taken by the turbine was ascertained under identical speeds and steam pressures as existed during the run. It might be well at this time to invite attention to the fact that as this is a constant-speed mill (except for slight variations caused by the governor on the turbine), and as there was but a comparatively small difference in the amount of coal contained in the mill at any time, irrespective of the different rates, there was little or no difference in the power taken by the mill proper. Any such differences as were found were probably due to personal errors in reading speed and therefore the power taken by the mill is taken as 18 kilowatts per hour at all rates of feed covered by this run.

It will be noticed that the power taken by the coal-feed motor is less at the higher rates than at the lower. This is due to the fact that during the lower rates the feeder was run at higher speeds than during the higher rates, but during the lower rates the position of the feeder knife was much nearer the edge of the disk than was the case during the higher rates, when the disk was rotated much more slowly but with the knife set at a much deeper angle.

CHECKING EQUIPMENT

All meters, gages, thermometers, and the calorimeter were calibrated before the run and checked after the run, and corrections to the recorded data made where necessary. All lines leading to air-pressure gages and all sampling tubes were blown out at hourly intervals immediately prior to the taking of readings. Fig. 7 is a line sketch of the entire set-up.

TWO HUNDRED AND FORTY-HOUR RUN

The boiler, which had been lighted and brought to working pressure the day before the run, was lighted (with oil) about one hour before the time set for starting the run, was brought to working pressure, valves were tested, and the fuel then changed from oil to coal. At 10.00 a.m., July 27, 1927, all conditions being settled, the run was started and it continued until 10.00 a.m., August 6, 1927, the rate at starting being 1,200 pounds of coal per hour which was increased by 200-pound increments at the end of each 48-hour period.

As previously stated, trouble was experienced occasionally with the feed pump, but, in addition, trouble was caused from time to time during the early days of the run by variations in the voltage of the power supplied to the motors. These variations were caused by load fluctuations on the navy yard circuits and were especially noticeable at the beginning and end of yard working hours and during the noon hour. During the last half of the run, trouble from this source was not encountered, as better arrangements covering power supply had been made.

Other troubles occurred from time to time either with the bucket conveyor, the screw conveyor, or the distributor, but all were overcome without interfering seriously with the run.

During the run at the 2,000-pound rate, trouble was experienced with the bearings of the primary air fan, making

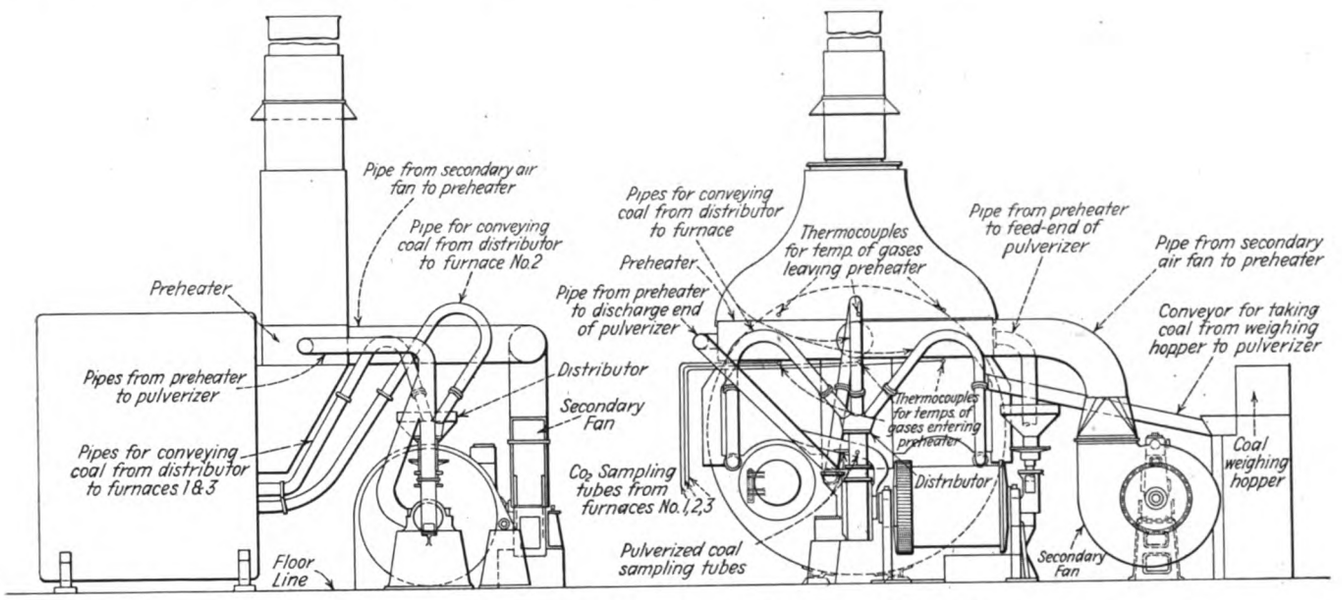
Pipe from secondary air fan to preheater
Pipe for conveying coal from distributor to furnace No.2
Preheater
Pipes from preheater to pulverizer
Pipes for conveying coal from distributor to furnaces 1&3
Distributor
Secondary Fan
Co2 Sampling tubes from furnaces No.1,2,3
Floor Line
Pipes for conveying coal from distributor to furnace
Thermocouples for temp. of gases leaving preheater
Preheater
Pipe from preheater to discharge end of pulverizer
Pipe from preheater to feed-end of pulverizer
Pipe from secondary air fan to preheater
Conveyor for taking coal from weighing hopper to pulverizer
Thermocouples for temps. of gases entering preheater
Distributor
Coal weighing hopper
Pulverized coal sampling tubes
Secondary Fan

Fig. 7.—Arrangement of pulverized coal equipment for tests

it impossible to maintain the air pressures previously found desirable, and, therefore, the results of this part of the run were not as good as were expected or as could have been obtained had no trouble been caused by the bearings of this fan.

The most serious trouble was experienced because of moisture in the coal, which was stored out of doors and which became thoroughly wet on more than one occasion during the heavy rains, as it could not be entirely protected in the open bunkers even though covered by canvas. During the early morning hours of July 31 it rained so hard that the exposed floor of the bunker had a considerable depth of water on it and it was necessary to cut holes in the deck to drain the water off. Under these conditions the coal fed to the mill was so wet at times that water ran from the weighing bin and actually dripped from the feeder disk.

An analysis of the coal on this watch showed 18 percent moisture. The mill continued to pulverize under these conditions, but the output was greatly diminished and the coal stream to the burners was extremely lean. There was, however, sufficient coal to keep the burners lighted except for one or two very brief periods, during which the oil burners were lighted. The total of these interruptions was so small that it can safely be forgotten in so far as concerns results, as the total oil used was less than 25 pounds and especially as it is doubtful if any coal as wet as this ever would be used on board ship.

It is to be noted that none of the difficulties encountered, except that with the primary air fan at the 2,000 pounds

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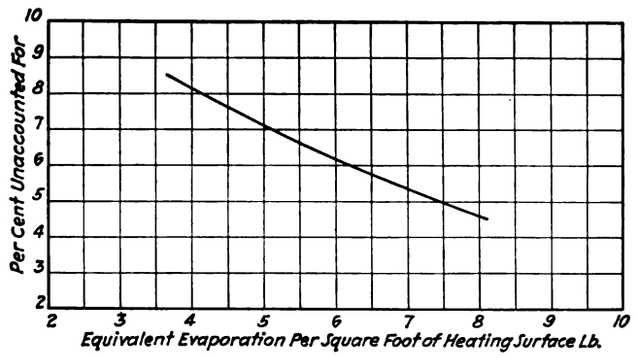

Fig. 8.—Curve showing percentage of unaccounted losses for various rates of evaporation when burning oil

per hour coal rate, were due to the pulverized-coal installation itself.

Tubes were blown by Diamond rear-end soot blowers at regular intervals throughout the run, these intervals being eight hours during the first two rates and four hours during the last three rates.

At the end of the run, after the boiler had cooled, all ash or residue in the furnaces, combustion chambers and smoke boxes was collected and weighed.

Steam made during the run, in excess of that used for steam-driven auxiliaries, was blown off at constant pressure to the atmosphere.

RESULTS

The results obtained on the 240-hour run, averaged for each of the 48-hour periods, or each of the five different rates of combustion maintained, are given in Table 1.

Attention is called to the heat release values obtained, as listed under "hourly rate fuel fired per cubic foot combustion space, B.t.u. Content." The values obtained on this test are not only unique in marine practice but also in stationary practice, as you will note that a rate of 59,984 British thermal units was maintained during the last 48-hour period.

In contrast to this value, it is to be noted that the average value obtained in stationary practice is somewhat less than 20,000 British thermal units. The highest value recorded in the latest report of the Prime Movers Committee on pulverized fuel is 41,600 British thermal units, which figure, moreover, is based on primary combustion space only, while the 59,984 British thermal units shown in this table takes into account the entire combustion space. If the primary combustion spaces or furnaces alone be taken, as they well might be, inasmuch as the flame did not extend beyond the horse collar of furnaces, this value would be over 141,600 British thermal units, or approximately 350 percent greater than the maximum heat release per cubic foot of furnace volume recorded for present stationary practice.

This high heat release has been accomplished by flame turbulence and high percentage of superfines in the pulverized coal.

The data relative to ash and refuse are based on samples collected in furnaces and smoke boxes at the termination of the 240-hour run. These values cannot be taken as truly representative, as the total amount found was approximately 2,300 pounds in furnaces and 3,500 pounds in the smoke boxes, or a total of 5,800 pounds, which is only 26 percent of the total amount of ash which was fired with the coal.

The greater part of the ash left the boiler and went out of the stack in the form of fly ash. The deposit in the furnaces and smoke boxes was made up chiefly of the larger particles not only of ash but also of coke. Along with the fly ash which went up the stack there was a certain amount of fly coke that had a relatively high heat content.

This fact, taken in conjunction with the high carbon dioxide conditions maintained, explains the comparatively low values shown for the weight of gas per pound of carbon fired, and also the low values for weight of gas per pound of fuel fired, as no correction can be made for combustible in ash and refuse in determining these values.

In computing the heat balance, it was at first considered advisable to combine the "Loss in combustible of ash and flue dust" with the "Loss unaccounted for." However, this is not satisfactory; thus an attempt has been made to segregate them in the following manner:

The unaccounted for loss consists chiefly of radiation losses. It was therefore felt that this factor would be approximately the same in this pulverized-coal test as in tests of this boiler when using oil.

A great number of oil-fired tests had been conducted on this boiler which made it possible to plot the curve shown in Fig. 8, which curve shows the percentage of unaccounted losses for various rates of evaporation when burning oil.

The "unaccounted for loss" shown in heat balance has been determined from this chart, while the "loss in combustible in ash and flue dust" is the value determined by deducting from the total heat content the summation of the items: (*a*) Heat absorbed by boiler; (*b*) loss due to moisture in fuel; (*c*) loss due to burning hydrogen; (*d*) loss carried away in dry gases; (*e*) loss due to carbon monoxide; (*f*) unaccounted loss determined from Fig. 8.

In order that maximum steaming rate and efficiency be maintained in a Scotch boiler, each of the furnaces should carry an equal share of the load. This requires equal distribution of not only the total coal but also the percentage of superfines. It may be noted from the individual furnace values of gas analysis and temperatures, also from the

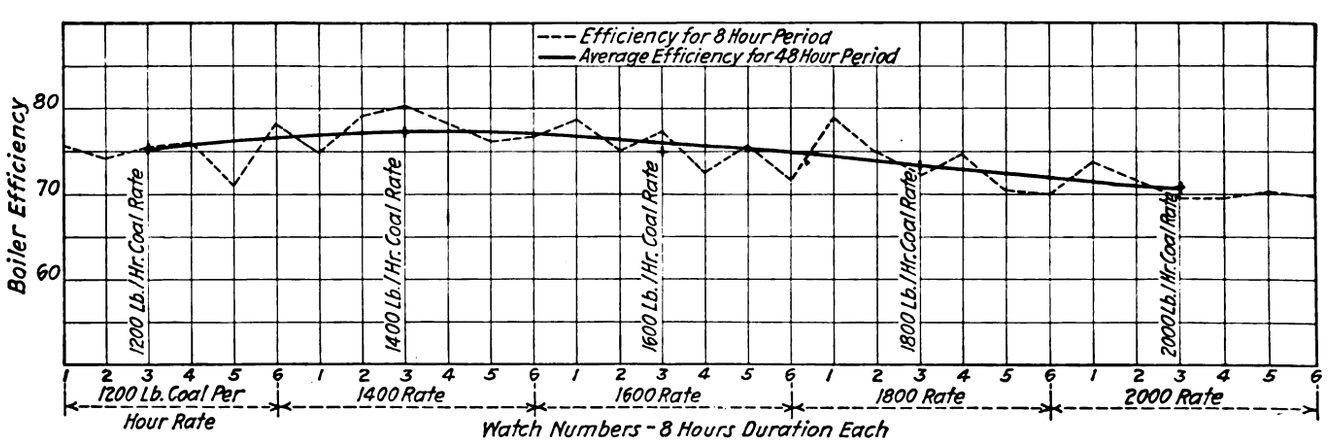

Fig. 9.—Graphic log of efficiencies obtained on each of the 8-hour watches of the 240-hour test

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TABLE I.—RESULTS OBTAINED ON 240-HOUR TEST OF PULVERIZED COAL USED IN CONNECTION WITH SCOTCH MARINE BOILER, AT THE FUEL OIL TEST PLANT, LOCATED IN PHILADELPHIA NAVY YARD.

Type of Boiler: Three furnace, separate combustion chambers Scotch marine boiler.

Type of Pulverizer: 4' by 5' air-swept Kennedy tube mill using ( ) pound ball charge.

Type of Burner: Peabody Engineering, turbulent combined coal and oil burner.

Heating Surface of Boiler:

Square feet heating surface, tubes	2,015
Square feet heating surface, combustion chambers	270
Square feet heating surface, furnaces	270
Square feet heating surface, total	2,555

Air Heater: Type—waste heat tubular. Square feet heating surface, 638.

Combustion Space:

Cubic feet, furnaces	199.18
Cubic feet, combustion chambers	270.79
Cubic feet, total	469.97

Note: The total volume of combustion space of bare boiler is 482.89; of this, however, 12.92 cubic feet was taken up by refractory ring at mouth of each furnace.

Retarders: Twisted ribbon type 4' 6" long—2½ turns in total length. All tubes retarded.

Coal: Bituminous, run of mine, Cambria County, Pennsylvania.

Test division number	I	II	III	IV	V
Date division rate started	7/27/27	7/29/29	7/31/27	8/2/27	8/4/27
Date division rate terminated	7/29/27	7/31/27	8/ 2/27	8/4/27	8/6/27
Duration (hours)	48	48	48	48	48
Total fuel as fired for period (lbs.)	57,859	66,395	76,767	86,422	94,808
Hourly rate—fuel fired (lbs.)	1,205.4	1,283.3	1,599.4	1,800.5	1,975.2
Hourly rate—fuel fired per burner (lbs.)	401.8	461.2	533.2	600.2	658.2
Hourly rate—dry fuel fired (lbs.)	1,180.1	1,354.2	1,558.2	1,757.2	1,919.8
Hourly rate—Combustible fired (lbs.)	1,111.4	1,258.8	1,466.6	1,667.3	1,799.4
Hourly rate—fuel fired per cu. ft. combustion space (lbs.)	2.57	2.94	3.40	3.83	4.20
Hourly rate—fuel fired per cu. ft. combustion space B.T.U. content	37,162	42,057	48,878	55,841	59,984
Hourly rate—fuel fired per sq. ft. heating surface (lbs.)	.471	.541	.626	.705	.773

COAL ANALYSIS—PROXIMATE

Test division number	I	II	III	IV	V
Moisture (%)	2.1	2.9	2.6	2.4	2.8
Fixed carbon (%)	72.1	70.9	71.7	72.2	70.0
Volatile (%)	20.1	20.1	20.0	20.4	21.1
Ash (%)	5.7	6.1	5.7	5.0	6.1
Heat value (B.T.U)	14,460	14,305	14,376	14,580	14,282

COAL ANALYSIS—ULTIMATE

Hydrogen (%)	4.9	4.8	4.9	4.8	4.8
Carbon (%)	81.8	80.7	81.3	82.2	80.6
Nitrogen (%)	1.4	1.2	1.3	1.3	1.3
Oxygen (%)	5.0	5.6	5.2	5.3	5.5
Sulphur (%)	1.2	1.6	1.6	1.4	1.7
Ash (%)	5.7	6.1	5.7	5.0	6.1

PULVERIZED COAL SCREENINGS

Through 50 mesh (%)	98.6	99.7	99.2	99.3	99.3
Through 70 mesh (%)	95.9	98.4	96.6	96.8	97.0
Through 100 mesh (%)	91.2	94.6	92.0	92.9	93.1
Through 140 mesh (%)	86.4	89.9	87.1	88.2	88.1
Through 200 mesh (%)	77.4	80.9	78.1	79.8	79.2
Through 300 mesh (%)	68.0	70.4	68.5	69.3	69.9

ASH AND REFUSE DATA

The ash and refuse for the 48-hour periods could not be segregated; therefore analysis date is based on composite sample.

Total weight ash in fuel fired (lbs.)	3,298	4,050	4,376	4,321	5,783
Fusion temperature of ash—average for 240-hour run	2,270° F.				
Combustible in ash and flue dust (%) for 240-hour run	35 (approx.)				
Non-combustible in ash and flue dust (%)	65 (approx.)				
Heat value of ash and flue dust (B.T.U.)	5,180				

GAS DATA

Pressures, inches of water:					
Rear of furnace—					
Furnace No. 1	—.159	—.28	—.25	—.239	—.242
Furnace No. 2	—.198	—.312	—.267	—.217	—.221
Furnace No. 3	—.172	—.298	—.222	—.171	—.107
Average	—.176	—.297	—.246	—.209	—.190
Below air heater	—.20	—.345	—.337	—.324	—.333
Above air heater	—.20	—.348	—.342	—.328	—.342
CO_2 (%)—					
Smoke box No. 1	15.99	16.94	16.98	16.6	15.46
Smoke box No. 2	16.05	16.44	17.15	17.20	16.42
Smoke box No. 3	16.50	16.77	16.92	17.50	16.90
Average	16.18	16.71	17.01	17.10	16.26
Oxygen (%)—					
Smoke box No. 1	2.80	1.66	1.78	2.41	3.93
Smoke box No. 2	2.81	2.30	1.58	1.30	2.41
Smoke box No. 3	2.33	1.96	1.80	1.02	2.00
Average	2.65	1.97	1.72	1.57	2.78
CO (%)—					
Smoke box No. 1	.002	0	.002	0	0
Smoke box No. 2	.004	0	.01	.12	.025
Smoke box No. 3	.009	0	.098	.119	.014
Average	.005	0	.037	.079	.013
Nitrogen (%)—					
Smoke box No. 1	81.21	81.40	81.24	80.99	80.61
Smoke box No. 2	81.13	81.26	81.26	81.38	81.15
Smoke box No. 3	81.16	81.27	81.18	81.36	81.09
Average	81.17	81.32	81.23	81.25	80.95

Test division number	I	II	III	IV	V
Temperatures (°F.);					
Gas leaving boiler—					
Smoke box No. 1	517	567	603	606	614
Smoke box No. 2	503	564	601	629	637
Smoke box No. 3	483	522	593	650	669
Average	501	551	599	628	640
Gas leaving air heater—					
Above furnace No. 1	436	477	532	553	553
Above furnace No. 2	403	428	471	507	521
Above furnace No. 3	406	451	504	535	540
Average	415	452	502	532	538
Weight of gas per lb. carbon fired (lbs.)	15.8	15.34	15.02	14.91	15.59
Weight of gas per lb. fuel fired (lbs.)	12.92	12.38	12.21	12.25	12.65

AIR DATA

Primary Air Pressures, inches of water—					
Discharged from fan	1.60	1.63	1.97	2.19	2.2
Head of coal and air—					
Line No. 1	1.38	1.50	1.65	1.78	2.07
Line No. 2	1.47	1.63	1.72	1.99	2.13
Line No. 3	1.27	1.43	1.45	1.58	1.86
Average	1.37	1.52	1.61	1.78	2.02
Burner Tuyere—					
No. 1	.91	.92	1.14	1.25	1.45
No. 2	.90	.85	1.07	1.20	1.13
No. 3	1.04	1.03	1.13	1.32	1.40
Average	.95	.93	1.11	1.26	1.33
Temperatures (°F.)—					
Feeder end of mill	145	134	132	133	108
Inlet to fan	150	142	142	147	148
At distributor	144	147	140	140	138
Secondary Air Pressures, inches of water—					
Double front	.53	.43	.56	1.03	1.23
Temperatures (°F.)—					
Wet bulb before air heater	75	76	76	65	84
Dry bulb before air heater	89	88	86	80	75
Air ducts leaving heater	197	199	202	201	198
At burner	214	217	215	211	206
Total weight of air per lb. of fuel fired (lbs.)	12.44	11.90	11.73	11.79	12.15
Excess air (%)	14.36	10.28	8.99	7.87	15.62
Barometer (inches)	30.15	30.08	30.01	30.16	30.13
Relative humidity (%)	51.28	56.13	63.70	46.80	49.40
Boiler-room temperature (°F.)	101	96	98	91	95

POWER REQUIRED FOR PULVERIZED COAL

Test division number	I	II	III	IV	V
K. W. per hour:					
Primary air fan	2.11	2.24	2.37	2.26	2.90
Coal feed	.15	.19	.13	.12	.07
Distributor	.31	.30	.33	.33	.21
Pulverizer	18.00	18.00	18.00	18.00	18.00
Total	20.57	20.73	20.83	20.71	21.18

STEAM AND WATER DATA

Boiler pressure absolute (lbs. per sq. in)	190.3	190.0	190.8	191.5	192.1
Temperature water to boiler (°F.)	208	209	211	207	210
Temperature steam in calorimeter (°F.)	307.6	307.8	307.8	308.2	308.7
Moisture in steam (%)	.20	.19	.19	.18	.16
Temperature of saturated steam (°F.)	377.72	377.60	377.92	378.25	378.54
Factor of evaporation	1.052	1.052	1.050	1.054	1.050

EVAPORATION DATA

Total weight water feed to boiler (lbs.)	615,315	718,873	811,266	906,293	935,762
Hourly rates (lbs.):					
Actual evaporation	12,820	14,977	16,901	18,881	19,495
Evaporation corrected for moisture	12,794	14,949	16,869	18,847	19,464
Equivalent evaporation from boiler	13,461	15,720	17,709	19,859	20,437
Actual evaporation per sq. ft. heating surface	5.01	5.86	6.61	7.38	7.63
Equivalent evaporation per sq. ft. heating surface	5.26	6.15	6.93	7.77	7.99

ECONOMIC RESULTS

Actual evaporation per lb. fuel fired (lbs.)	10.61	10.81	10.54	10.46	9.86
Equivalent evaporation per lb. fuel fired (lbs.)	11.16	11.36	11.07	11.02	10.34
Equivalent evaporation per lb. dry coal fired	11.41	11.61	11.37	11.30	10.65

HEAT BALANCE (BASED ON LBS. OF COAL AS FIRED)

Heat absorbed by boiler (B. T. U.)	10,829.7	11,023.7	10,742.3	10,693.8	10,033.9
Heat absorbed by boiler (%)	74.89	77.06	74.72	73.35	70.26
Loss due to moisture in fuel (B.T.U.)	24.95	33.6	32.0	30.0	35.3
Loss due to moisture in fuel (%)	.17	.24	.22	.21	.25
Loss due to burning hydrogen (B. T. U.)	523.91	521.3	543.1	541.1	549.9

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Table I (Continued from page 667)

Loss due to burning hydrogen (%)	3.62	3.64	3.78	3.71	3.85
Loss carried away in dry gases (B. T. U.)	1,004.35	1,077.7	1,211.4	1,327.4	1,405.4
Loss carried away in dry gases (%)	6.95	7.53	8.43	9.10	9.84
Loss due to carbon monoxide (B.T.U.)	2.56	0	26.1	38.3	6.5
Loss due to carbon monoxide (%)	.02	0	.18	.26	.04
Loss in combustion in ash and flue dust (B.T.U.)	1,076.79	776.1	1,037.7	1,249.5	1,593.9
Loss in combustion in ash and flue dust (%)	7.45	6.43	7.22	8.57	11.16
Loss unaccounted for, radiation, etc.: (B.T.U.)	997.74	872.6	783.4	699.9	657.1
(%)	6.90	6.10	5.45	4.80	4.60
Fuel as fired (B.T.U. per lb.)	14,460	14,305	14,376	14,580	14,282

separate primary air pressures recorded in Table 1, that perfect distribution was not obtained during the run, as previously mentioned. The degree of variance shown, however, was not of sufficient magnitude to seriously affect operating conditions.

The development of a distributor, which under all load conditions will maintain perfect distribution, is especially to be desired. When this is effected, it will be possible to obtain regularly in service the 80 to 83 percent boiler efficiencies that have been obtained on several of the short period runs made at the test plant.

A graphic log of the efficiencies obtained on each of the eight-hour watches of the 240-hour test is shown in Fig. 9. On the chart is given also the efficiency curve obtained from the average values of each of the 48-hour periods. This shows a comparatively flat curve ranging between 70.26 and

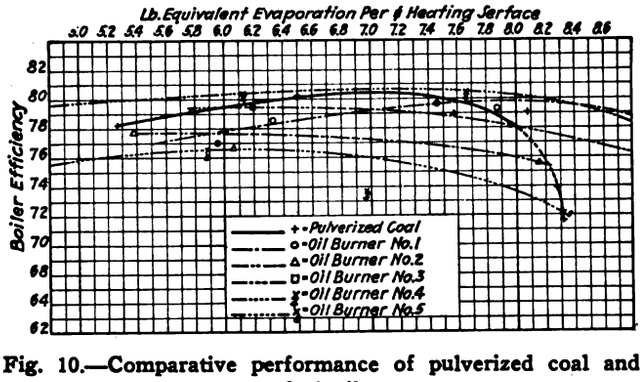

Fig. 10.—Comparative performance of pulverized coal and fuel oil

77.06 percent which may be compared with the 60 to 65 percent generally found in the case of hand-fired service conditions and is approximately the same as is obtained with oil-fired service conditions.

Unfortunately a continuous service test such as the 240-hour pulverized-fuel test described herein has not been made with oil fuel on this boiler, and so a direct comparison is impossible with the values shown in Fig. 9.

However, several oil burners have been tested on this same boiler, the efficiency curve for these burners being determined from two-hour peak periods during the day's run.

It is felt, therefore, in order to make a comparison between the results obtained with pulverized fuel and the results obtained with fuel oil, that the peak periods of the 240-hour test should be used for determining the pulverized coal characteristic efficiency curve. In this case, however, instead of two-hour periods, eight-hour periods have been taken.

As there is a difference in the heat content of coal and oil, the comparison between the two fuels must be based on some factor other than weight.

The factors selected in drawing up Fig. 10, on which this comparison is shown, are boiler efficiency plotted against equivalent evaporation per square foot of heating surface. It is to be noted that of the five commercial burners plotted on the chart only one shows an efficiency rate in excess of the pulverized coal for evaporation rates less than 7.5 pounds per square foot of heating surface.

In reference to burner No. 4, which tops the pulverized-coal curve, it may be stated that this burner has positive control of air supply to each individual burner. This in a manner effects the condition which would be obtained with perfect distribution in the case of the pulverized-fuel installation.

It is probable that the drop in the pulverized-fuel curve of Fig. 10, as indicated by the dotted section for evaporation rates in excess of 8 pounds per square foot of heating surface, is somewhat greater than it should be. These points were determined from values obtained after 200 hours steaming when the boiler had become scaled from the 3,000,000 pounds or more of water which had been evaporated and discharged to the atmosphere. This, of course, would affect the efficiency figures.

Moreover, during the particular run for which these figures were obtained, trouble was experienced with the primary fan bearings which made it necessary to run with 2.2-inch discharge pressure instead of the contemplated 2.7-inch pressure, a condition that reduced the turbulence of the flame and so affected efficiency of combustion.

With the latter mentioned defect corrected and with clean boilers, the performances obtained would probably have plotted between curve of burner No. 3 and burner No. 4 as, in fact, the 8.08 rate does plot.

CONCLUSION

The writers of this paper feel that it would have been preferable to have delayed its preparation until the installation which is now being made on the S. S. *Mercer* had been completed and given a real sea-going service test. However, in view of the general interest that has been displayed by the marine engineering world in the progress of the test work, it was considered advisable to take advantage of the request made by the Naval Architects and Marine Engineer's Society and present the data given to the engineering profession.

Considerable development work has been accomplished in adapting pulverized fuel to marine practices, but additional development is still required. Further pioneer work can be accomplished at the test plant; but, with the initial difficulties now solved, it is believed that it can be best accomplished on board operating vessels.

The main purpose, therefore, of this paper is to stimulate the development work by the ship operators themselves. The initial water-borne pulverized-fuel plant which has been made on the towboat *Illinois* by the Inland Waterways Commission is a step in the right direction.

The installation which is being made on the S.S. *Mercer* will be of paramount importance in solving the problem. Most commendable research work is being carried on by the manufacturers of pulverized fuel equipment such as the "Bayonne" and "Framingham" tests. The final completed product, however, that can be accepted as a standard will eventually be evolved not alone from these test installations made by the government and the manufacturers but from a number of sea-going jobs which the operators of our merchant marine tonnage will themselves install.

THE DEPARTMENT OF COMMERCE reports 80 steam, motor, sail and unrigged vessels of 9,290 gross tons built in the United States and officially numbered during the month of October, 1927. This includes 32 vessels of 3,576 gross tons built in previous years.

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Pulverized Coal Tests of Marine Watertube Boiler*

Tests with standard Babcock and Wilcox water-tube boiler show that pulverized coal can be burned efficiently at high rates of combustion

By Thomas B. Stillman

DURING the last few months the Babcock & Wilcox Company has been conducting a series of experiments at its Bayonne plant using pulverized coal under a standard Babcock & Wilcox marine boiler built in

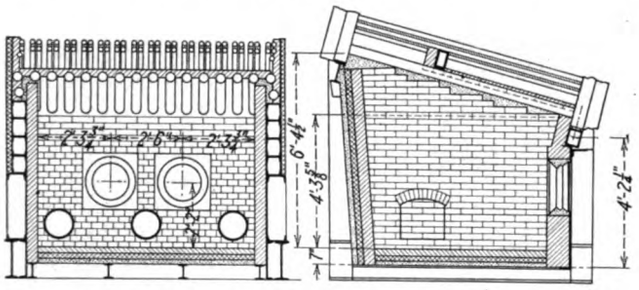

Fig. 1.—Sections through furnace of boiler

1910. The tubes were 8 feet long between headers, the boiler being 16 headers wide. Each header had one 4-inch tube in the furnace, or bottom row, and above that nine

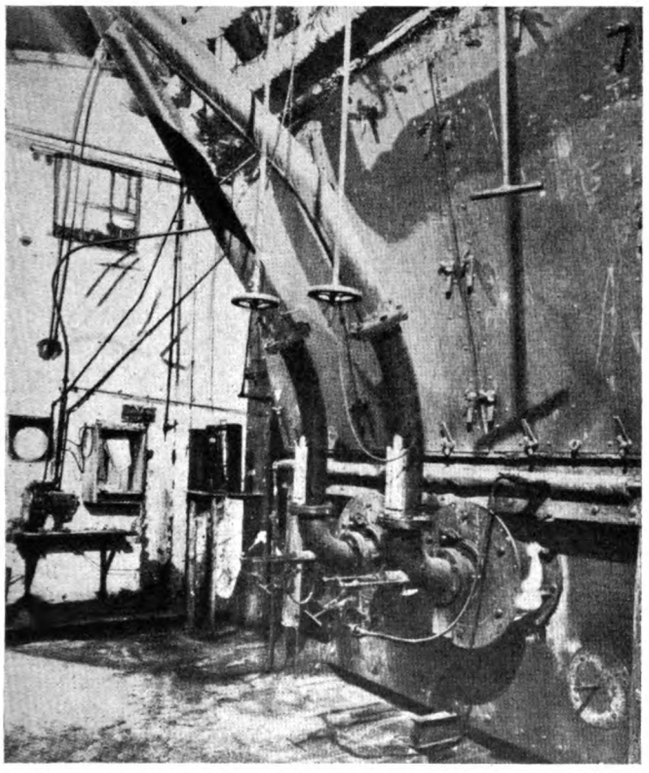

Fig. 2.—View of boiler showing arrangement of pulverized coal burners

groups of four 2-inch tubes. The total heating surface of the boiler was 2,755 square feet and the furnace volume 250 cubic feet.

*Paper read at the thirty-fifth general meeting of the Society of Naval Architects and Marine Engineers, New York, November 11, 1927.

Fig. 1 shows a longitudinal and front view section of the furnace. It may be noted that the side walls had cross boxes in them, but for the pulverized coal experiments these were covered with 4½ inches of brick and ½ inch asbestos, so that, for all practical purposes, the furnace could be regarded as not having any water-cooled surface in it except the bottom row of boiler tubes, which were exposed their full length. The boiler was fitted with a small Babcock & Wilcox superheater located at the top of the first and second passes of the boiler. No air heater was used with the boiler; diamond soot blowers were fitted to the boiler and superheater. Fig. 2 shows the front of the boiler fitted with the two pulverized coal burners.

The pulverizing equipment supplied by the Fuller Lehigh Company consisted of a No. 2 Fuller Bonnot unit

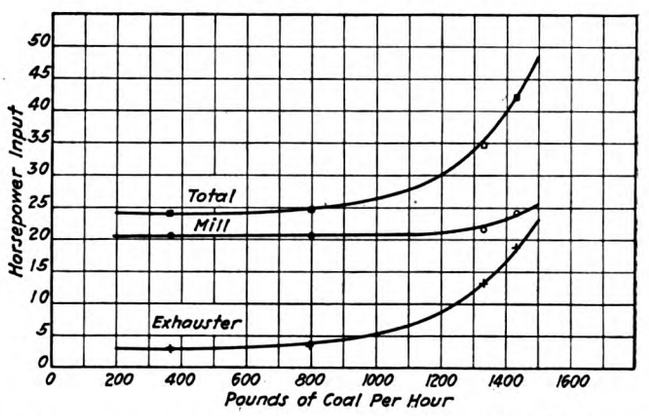

Fig. 3.—Curves showing horsepower input to No. 2 Bonnot mill and No. 7 Buffalo forge exhauster

ball mill fitted with a No. 7 Buffalo forge fan for exhauster. Both mill and fan were electrically driven, so that the power requirements could readily be determined on these two pieces of apparatus for different quantities of coal handled. Fig. 3 shows this horsepower input graphically for the mill and fan separately and also the total of the two. These curves, which were obtained in the early part of the experiments, were frequently checked during the progress of the tests reported in this paper, and, although slight variations were recorded from time to time, they may be regarded as representative of the power used over the range covered and have accordingly been used for obtaining Items 54-55-56-57 in Table 1.

The boiler was operated "natural draft" with an open fire room at all times; if drafts greater than the 0.45-inch available from the 100-foot stack were needed, a steam jet was used.

The earlier experiments were devoted primarily to the development of a burner which would satisfactorily handle the necessary amount of coal in the small furnace available, with an acceptable efficiency. In modern central station practice it has not been found desirable, with the types of pulverized coal burners used, to exceed a rate of 30,000 British thermal units per cubic foot per hour under peak load conditions. This *peak rate* limitation in the

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stationary field is only about half the rate that would be necessary in the average marine furnace for *normal* operation, and accordingly the necessity of developing a new burner for marine furnaces, having a very rapid speed of combustion, will be appreciated. Altogether, some seven or eight different types of burners were made up and tried out before the final satisfactory design was installed. This satisfactory burner is shown in Fig. 4, and its similarity to a standard mechanical oil burner may be noted. With the exception of the coal-conveying pipe coming through the register cover plate, all parts of the burner are the same as those used in the Babcock & Wilcox Lodi type oil burner. Accordingly, a connection was made in the cast iron elbow of the coal pipe so that a Babcock & Wilcox mechanical oil atomizer could be inserted, and the burner used as an oil burner if it were desired to do so. This will be a convenience on some ships where it would be preferable to use oil instead of coal for maneuvering and port conditions.

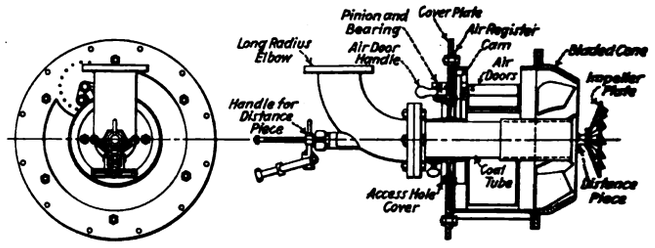

Fig. 4.—Pulverized coal burner

When this type of burner was first used, we always used oil for starting and putting the boiler on the line, later

TABLE 1.—TESTS OF BABCOCK & WILCOX MARINE BOILER FITTED WITH A BABCOCK & WILCOX SUPERHEATER AND TWO BABCOCK & WILCOX PULVERIZED COAL BURNERS

Pulverized coal supplied by No. 2 Fuller-Bonnot mill and No. 7 Buffalo forge fan
Boiler heating surface, 2,755 square feet. Furnace volume, 250 cubic feet

1	Date of test, 1927	7/25	7/26	7/27	7/28	7/29	8/4	8/5	8/11	8/16	8/17
2	Duration (hours)	4½	7	5	6	7	7	6	5	6	6
3	Type of coal used	Dundon gas slack—West Virginia								Pocahontas	
4	Speed of mill (R. P. M.)	32	32	32	32	32	32	32	32	32	32
5	Speed of exhauster (R. P. M.)	1,670.3	1,819.3	2,258.1	1,878.4	2,247.0	2,031.0	1,842.0	2,350.0	2,336.8	2,336.0
	Steam Pressures (lbs.-sq. in.):										
6	Drum	205.1	192.3	191.0	187.1	191.0	185.1	205.3	176.3	183.3	187.0
7	Superheater inlet	203.3	189.5	188.5	186.2	189.3	184.5	205.0	178.0	182.2	186.4
8	Superheater outlet	202.0	187.0	187.3	185.6	187.6	183.9	204.7	180.2	180.7	184.7
	Temperatures (° F.):										
9	Furnace	2,126.1	2,237.3	2,302.2	2,252.1	2,291.1	2,255.9	2,078.0	2,483.5	2,450.6	2,535.3
10	Gas-uptake	420.8	424.2	465.4	442.7	479.6	440.2	424.2	471.3	468.1	454.4
11	Feed water	170.6	196.0	197.9	80.9	80.4	197.6	201.7	189.5	195.5	186.4
12	Superheated steam	438.3	431.0	455.6	444.5	458.6	428.1	429.9	442.7	451.7	449.8
13	Room	92.5	101.3	102.0	103.0	102.8	93.5	99.2	98.3	89.5	94.6
14	Air entering mill	166.5	169.0	183.8	185.9	188.5	183.9	187.2	147.6	166.5	.....
15	Calorimeter—superheater inlet	312.6	310.5	310.1	310.1	309.9	308.6	313.0	307.3	308.5	308.3
	Drafts (in H_2O):										
16	Furnace	.069	.086	.364	.053	.283	.049	.019	.167	.339	.568
17	Uptake	.269	.324	1.321	.538	1.299	.213	.076	.543	.875	1.206
18	Air pressure in burner pipe	2.20	2.59	4.36	2.99	4.27	2.01	1.46	2.61	2.435	2.35
	Gas Analysis (%):										
19	Top of 1st pass... CO_2	13.63	13.72	13.17	13.54	13.70	13.24	13.34	13.09	13.45	13.82
20	Top of 1st pass... O_2	5.53	5.29	5.89	5.51	5.22	5.66	5.66	5.89	5.55	5.28
21	Top of 1st pass... CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Top of 1st pass... N_2	80.84	80.99	80.94	80.95	81.08	81.10	81.00	81.02	81.00	80.90
23	Uptake..... CO_2	12.57	13.22	12.40	12.35	12.39	11.25	12.68	12.00	12.16	12.57
24	Uptake..... O_2	6.48	6.17	6.52	6.53	6.68	7.65	6.30	6.94	7.30	6.67
25	Uptake..... CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	Uptake..... N_2	80.95	80.61	81.08	81.12	80.93	81.10	81.02	81.06	80.54	80.76
27	Quality of smoke	Light gray ash									
28	Total water evaporated (lbs.)	31,443.0	60,812.0	68,531.0	53,108.0	84,156.0	55,490.0	32,885.0	50,160.0	64,465.0	70,830.0
29	Total wet coal to burners (lbs.)	3,377.0	6,063.0	7,189.0	6,230.0	9,865.0	5,744.0	3,365.0	5,262.0	6,330.0	7,050.0
30	Moisture in coal entering mill (%)	3.55	2.48	2.84	4.82	4.27	5.06	6.22	3.53	4.55	3.93
31	Moisture in coal leaving mill (%)	1.07	.94	1.08	1.22	1.35	1.27	1.47	1.23	.63	.76
32	Quality of steam S. H. inlet (%)	99.93	99.91	99.90	99.92	99.88	99.87	99.93	99.84	99.81	99.86
33	Calculated saturated steam temperature at S. H. outlet (° F.)	388.68	382.58	382.70	382.02	382.82	381.24	389.66	379.75	379.96	381.60
34	Degrees superheat at S. H. outlet (° F.)	49.42	48.02	73.00	62.38	75.98	46.86	40.24	62.95	75.94	69.10
35	Factor of evaporation	1.1262	1.0973	1.1099	1.2242	1.2326	1.0946	1.0888	1.1119	1.1130	1.1192
36	Total water F & A 212° F. (lbs.)	35,399.8	66,729.0	76,062.6	65,014.8	103,730.7	60,739.4	35,805.2	55,772.9	71,749.5	79,272.9
37	Water evaporated per hour, actual (lbs.)	6,985.1	8,687.4	13,706.2	8,851.3	12,022.3	7,927.1	5,480.8	10,032.0	10,744.2	11,805.0
38	Water per hour F & A 212° F. (lbs.)	7,866.6	9,532.7	15,212.5	10,835.8	14,818.7	8,677.1	5,967.5	11,154.5	11,958.3	13,212.2
39	Water per hour F & A 212° F. per sq. ft. of H. S. (lbs.)	2.86	3.46	5.52	3.93	5.38	3.15	2.17	4.05	4.341	4.796
40	Total dry coal (lbs.)	3,257.17	5,912.6	6,984.8	5,929.7	9,443.8	5,453.4	3,155.7	5,076.3	6,042.0	6,773.0
41	Wet coal per hour (lbs.)	750.4	866.1	1,437.8	1,038.3	1,409.3	820.6	560.8	1,052.4	1,055.0	1,175.0
42	Dry coal per hour (lbs.)	723.8	844.7	1,397.0	988.3	1,349.1	779.1	526.0	1,015.3	1,007.0	1,128.8
43	Dry coal burned per cu. ft. of F. V. per hour (lbs).	2.90	3.38	5.59	3.95	5.40	3.12	2.10	4.06	4.03	4.52
44	Dry coal burned per sq. ft. of H. S. per hour (lbs.).	.263	.307	.507	.359	.490	.283	.191	.369	.366	.410
45	Wet coal per burner per hour (lbs.)	375.2	433.05	718.9	519.2	704.7	410.3	280.4	526.2	527.5	587.5
46	Dry coal per burner per hour (lbs.)	361.9	422.4	698.5	494.2	674.6	389.6	263.0	507.7	503.5	564.4
47	B. T. U. liberated per cu. ft. of F. V. per hour	37,642.0	44,632.9	75,062.5	52,507.4	71,366.4	41,939.0	27,680.1	52,897.7	57,036.6	63,876.6
48	Actual evaporation per lb. of dry coal (lbs.)	9.65	10.28	9.81	8.96	8.91	10.17	10.42	9.88	10.67	10.46
49	Equivalent evaporation per lb. of dry coal (lbs.)	10.87	11.29	10.89	10.96	10.98	11.14	11.35	10.99	11.88	11.70
50	Total air supplied per hour (lbs.)	9,880.6	11,561.4	20,199.2	13,806.6	18,389.6	11,099.8	7,353.5	14,224.4	15,014.4	16,559.5
51	Primary air per hour (lbs.)	.....	7,372.9	8,825.4	7,117.3	7,598.2	7,008.8	4,327.2	.....	7,612.0	7,574.4
52	Percent primary air	.....	63.77	43.69	51.55	41.32	63.14	58.85	.....	50.70	45.74
53	Percent excess air used for combustion	34.98	32.88	38.05	34.74	32.24	35.94	36.01	37.88	35.06	32.84
54	Horsepower input, mill	20.7	20.8	24.2	21.0	23.6	20.8	20.8	20.9	20.8	21.0
55	Horsepower input, exhauster	3.8	4.5	18.7	6.1	17.2	4.2	3.2	6.2	7.1	7.3
56	Total H.P. of mill and exhauster	24.5	25.3	42.9	27.1	40.8	25.0	24.0	27.1	27.9	28.3
57	Total H.P. of mill and exhauster per 1,000 lbs. wet coal per hour	32.64	29.29	29.83	26.10	28.91	30.47	42.79	25.75	26.45	24.09
58	B. T. U. per lb. of dry coal	12,980	13,205	13,428	13,293	13,216	13,442	13,181	13,029	14,153	14,132
59	Efficiency—boiler, superheater and furnace (%)	81.27	82.97	78.70	80.01	80.62	80.42	83.56	81.85	81.46	80.34
	Heat Balance (%):										
60	Heat absorbed by boiler	81.27	82.97	78.70	80.01	80.62	80.42	83.56	81.85	81.46	80.34
61	Loss due to moisture in coal	0.34	0.23	0.26	0.45	0.41	0.68	0.60	0.34	0.41	0.35
62	Loss due to water from combustion of H_2	4.11	4.01	4.01	4.01	4.09	3.99	4.03	4.15	3.27	3.24
63	Loss due to dry chimney gases	9.10	8.40	9.87	9.35	10.41	10.31	8.81	10.77	10.85	10.01
64	Radiation and unaccounted for losses	5.18	4.39	7.16	6.18	4.47	4.80	3.00	2.89	4.01	6.06
65	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Fineness of Coal (%):										
66	Through 48 mesh	99.8	99.8	99.6	99.6	99.6	.....	99.8	99.8	99.8	99.8
67	Through 100 mesh	97.4	94.8	93.4	93.0	89.4	.....	98.2	93.4	97.0	96.0
68	Through 200 mesh	83.0	78.0	75.6	72.0	66.2	.....	89.0	74.6	72.6	77.6
	Furnace Ash Analysis (%):										
69	Combustible	.....	0.15	0.05	0.80	0.00	.....	0.36	0.50	0.07	0.00
70	Ash	.....	99.85	99.95	99.20	100.00	.....	99.64	99.50	99.93	100.00
	Uptake Dust Analysis (%):										
71	Combustible	7.47	6.39	15.18	9.05	23.84	9.93	4.42	6.23	16.22	14.88
72	Ash	92.53	93.61	84.82	90.95	76.16	90.07	95.58	93.77	83.78	85.12

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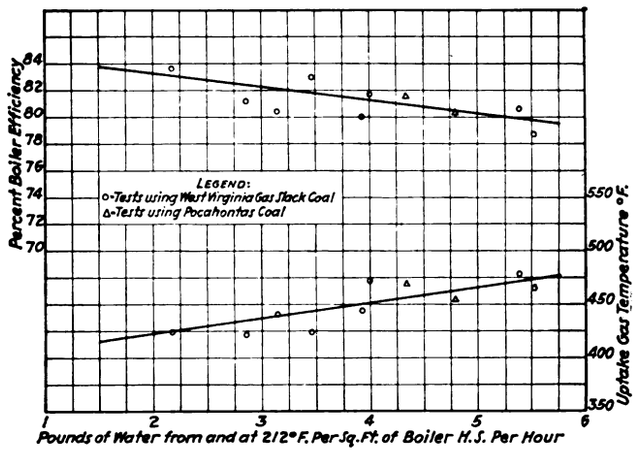

Fig. 5.—Curves showing boiler efficiencies and uptake gas temperatures, using Bonnot mill

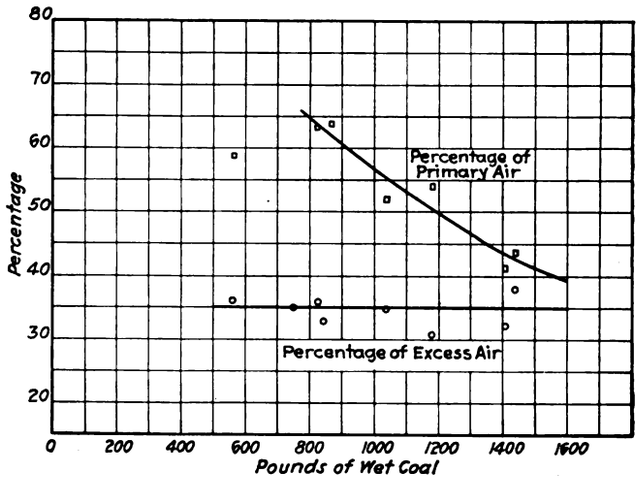

Fig. 6.—Curves showing percentages of primary air used in mill and excess air used for combustion. Tests using Bonnot mill

shifting to coal after everything was heated. During the last few months, however, the oil connection has never been used, the pulverized coal being lighted in the cold furnace with an oil-soaked torch, in much the same manner as when lighting a mechanical oil burner.

Although this burner will burn either coal or oil efficiently, the location of the impeller plate when burning coal is quite different from that which should be used when burning oil. Fig. 4 shows the impeller properly located for burning coal, but for oil this should be pulled back from the furnace about 6 inches, to insure a satisfactory mixture of the air and the atomized oil.

As the coal came to the mill with various percentages of moisture, it was necessary to have some preheat in the air going to the mill; and in the absence of an air heater on the boiler, a small steam coil was built near the entrance to the mill, so as to give the primary air a temperature between 150 and 190 degrees F. as it entered the mill, the temperature depending upon the rate the mill was operating. By the time this air reached the burners its average temperature was 105 degrees F., the drop being caused by evaporation of the moisture in the coal and radiation from the mill and conveying piping. As the temperature of this air entering the burners was only a few degrees above room temperature, it was unnecessary to make any allowance for it in the boiler efficiency calculations.

With the equipment described above, a series of tests was run the latter part of July and the first part of August, 1927, the complete tabulation of these boiler tests being given in Table 1. The first two columns of Table 2 give representative proximate and ultimate analyses of the coals used, the first being the regular Bayonne Power Plant coal, the second being a special shipment of Pocahontas secured for experimental purposes (used in tests of August 16 and 17).

TABLE 2.—COAL ANALYSES

	Dundon gas slack Dundon, W. Va.	Pocahontas screened coal West Virginia	Run of mine gas coal Fleming, W. Va.
Ultimate Analysis of Dry Coal			
Carbon	74.75	81.59	73.07
Hydrogen	4.97	4.24	5.03
Nitrogen	1.39	1.18	1.33
Sulphur	.78	.59	4.53
Ash	11.79	10.20	10.35
Oxygen	6.32	2.20	5.69
Proximate Analysis			
Moisture	4.94	4.24	3.77
Volatile matter	34.50	16.23	37.41
Fixed carbon	53.71	73.57	52.24
Ash	11.79	10.20	10.35
Sulphur	.78	.59	4.53
Fusing point of ash °F*	2,710	2,705	2,020

* Defined as Softening Temperature in A. S. T. M. Specification D-22-24.

Fig. 5 shows graphically the boiler efficiencies and uptake gas temperatures secured in these tests. Fig. 6 shows in the upper curve the percentage of primary air used for conveying the coal from the mill to the burners, and the percentage of excess air used in the combustion of the coal. Fig. 7 is a graphical representation of the heat balances, showing distribution of the heat fired in the coal.

On all of these tests the coal and water were accurately weighed on calibrated scales, and all pressures and temperatures were taken with calibrated gages, thermometers or pyrometers. The furnace temperatures recorded are an average of readings taken at three different points in the furnace with an optical pyrometer. Two samples of coal were taken for each test, one of the coal being weighed before going to the mill, and the other after leaving the mill. The British thermal units and moisture value of the former were used for calculating efficiencies, heat balances, etc., and the latter for fineness of the product from the mill. Samples were also taken of the furnace ash and of the dust in the uptake gases, both of these being analyzed for percentage of combustible and ash.

In running these tests it was customary to start the boiler Sunday night or Monday morning and continue it in service till Friday night. The first thing every morning, when the day shift came on, the furnace was cleaned of ashes, and the boiler and superheater were given a dusting with the soot blowers. Conditions would then be steadied for

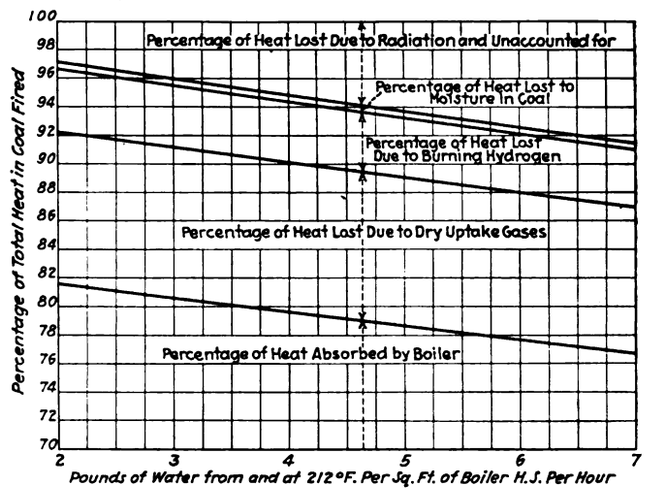

Fig. 7.—Curves showing heat balance using Bonnot mill

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a test at the rate desired. Only one test was run per day. The night shift did no testing but operated the boiler at a given rate (usually about 800 to 1,000 pounds of coal per hour) and recorded the weight of coal burned. In this way a record was secured of the total coal fired during the week. The ash removed from the furnace every morning was weighed, resulting in the figures given in Table 3, these showing that between 13 and 21 percent of the ash fired in the coal remained in the furnace, the rest of the ash passing through the boiler to the uptake.

At all times during the tests, the top of the stack showed a light, almost white discharge which consisted of fine ash. No smoke was made by the burners used in the tests until the CO_2 exceeded 17 percent, when a distinct color became visible at the top of the stack. If the air was reduced still further, heavy black smoke could be made and the burners would show a tendency to start pulsating.

The percentage of excess air used for combustion was maintained at approximately 35 percent (13½ percent CO_2), as preliminary experiments had shown that a higher amount of CO_2 did not appreciably affect the boiler efficiency, but, on the contrary, did increase the operating difficulties with furnace slag, especially at the higher rates. As the furnace temperature approached the fusing point of the ash in the coal, the slag began to strike and stick to the tubes at the bottom of the first pass and gradually bridge across the same, shutting off the gas opening from the furnace. By running with 35 percent excess air, the furnace temperatures were kept at a point where the slag gave no trouble from this source. In a similar manner, the excess air used assisted in preventing the ash in the furnace from fusing with or adhering to the furnace brickwork, a condition that occurred when the excess air was reduced too much.

The removal of the ashes from the furnace each morning was a relatively simple operation during these tests, an ordinary hoe and devil's claw being used. The ash which had lodged in the corners and on the floor was in a porous, coral-like formation, which was readily dislodged and removed through the three clean-out doors provided in the furnace front plate at the floor level. The burners were not shut down while this was being done, as experience showed that the ash came out best when both burners were kept in operation at a reduced rate (about 300 pounds of coal per burner per hour). The removal of the ashes from the furnace is undoubtedly a hot, dusty operation, but as it would never have to be done oftener than once every twenty-four hours, and usually less often than that, it need not be regarded as a serious matter in the burning of pulverized coal. After the ashes are out on the floor, they may be disposed of with ash ejectors in the usual way.

The appearance of the flame in the furnace during these tests was excellent, and more attractive in some respects than that secured with oil. The flame was short and well distributed through the furnace, and sufficiently clear so that, when looking throgh a blue-glass peep-hole in the rear wall, parts of the burner could be seen, thus forcibly illustrating the high speed of combustion being secured with these burners.

AIR HEATERS

Although we did not have an air heater for the tests at Bayonne, in general their use is undoubtedly a distinct advantage with pulverized coal. Aside from the direct gain in efficiency due to reduction in uptake gas temperature, they also provide a simple method of heating the primary air going to the mills, in place of steam heaters. Also using preheated air should serve to increase the speed of combustion in the furnace, reducing the possibility of unconsumed carbon escaping up the stack. The larger the "unaccounted and radiation losses" recorded during a test *without* an air heater, the more valuable the use of an air heater would be.

The possible disadvantages of an air heater with pulverized coal are:

1. Increase in furnace temperature with the chance of increasing this beyond the fusing point of the ash, which might not occur with atmospheric air.

2. In the case of "tarry" coals the plugging up of portions of the pulverized coal equipment, due to the "tarry" nature of the coal when preheated by the air.

ASH AND SLAG

As indicated above, no difficulty was experienced with the ash either in the furnace or on the tubes during the tests recorded herewith. If at any time, during high ratings, with high CO_2, the ash started to build across the tubes at the bottom of the first pass, it was readily dislodged with a steam lance inserted through a peep-hole in the side casing without shutting the fires off. At rates below 80,000 British thermal units per cubic foot and with 14 percent CO_2 or less, neither the Dundon nor Pocahontas coal showed any tendency to bridge across the bottom of the first pass, nor was any ash deposited in the furnace which was difficult to remove.

TABLE 3.—WEIGHTS AND PERCENTAGES OF FURNACE ASH

Date	7/21–7/22	7/25–7/29	8/2–8/6	8/10–8/12	8/16–8/19
Number of hours of operation	12.60	106.33	77.33	53.78	77.00
Total wet coal fired, lbs.	14,245	95,464	62,684	50,617	74,505
Average percent of ash in coal	14.76	11.66	12.17	13.98	9.23
Total ash in coal, lbs.	2,102.6	11,131.1	7,650.5	7,076.3	6,876.8
Total slag removed from furnace, lbs.	450	2,070	1,060	904	1,373
Average percent of ash in slag	99.75	99.75	99.72	99.55	99.98
Total ash in slag removed from furnace, lbs.	448.9	2,064.8	1,057.0	899.9	1,372.7
Percentage of total ash fired remaining in furnace	21.34	18.55	13.82	12.72	19.96

Realizing that the satisfactory results secured with the ash and slag of the Dundon and Pocahontas coals were largely due to the high fusing points of the ash content of these coals, some coal was secured from Fleming, W. Va., having a fusing point of approximately 2,000° F. This coal had an ultimate analysis and proximate analysis as shown in the third column of Table 2, the British thermal unit value per pound of dry coal being 13,800. When this coal was fired the ash and slag conditions in the furnace underwent a radical change. The ash and slag striking the boiler tubes would build up a small deposit at the bottom but did not have physical strength enough to show any tendency to bridge across from tube to tube. As the deposits at the lower edge of the tubes gradually built up, the molten slag would drip off, falling to the furnace floor in long drops. Sometimes the slag would build up a little too much on the tube to adhere longer, and sections of the hardened as well as plastic slag would drop off, leaving the bare tube exposed, on which fresh slag immediately started to build.

The furnace walls were quickly covered with a coating of the slag, this proceeding to run down the faces of the walls before the deposit reached any appreciable depth, a maximum of 1 inch being about the limit to which this deposit would build. Later, when it was attempted to remove this deposit with the furnace shut down, the face of the brick came with it. The corners where the walls and floor met were filleted with a partially porous ash and slag deposit which was plastic on the surface and relatively hard underneath. The deposit on most of the floor was sufficiently plastic to seek its own level, this looking like a sheet of black glass when the furnace was shut down.

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At the end of the first twenty-four hours run with this coal, efforts were made to remove some of this slag from the furnace with the burners in operation, but the results were unsuccessful. The material filleted in the corners was too hard to be dislodged with slice bars except at the surface, which was plastic, this portion sticking to the tools like taffy. The material in the center of the floor acted in a similar manner and could not be handled. After forty-eight hours running with this coal, the boiler was shut down and the ash and slag deposits removed from the floor and fillets with hammers, chisels and pickaxes.

This low fusing ash had one advantage compared to the high fusing type, namely, that the boiler could be operated more than twice as long without the slag deposit on the floor

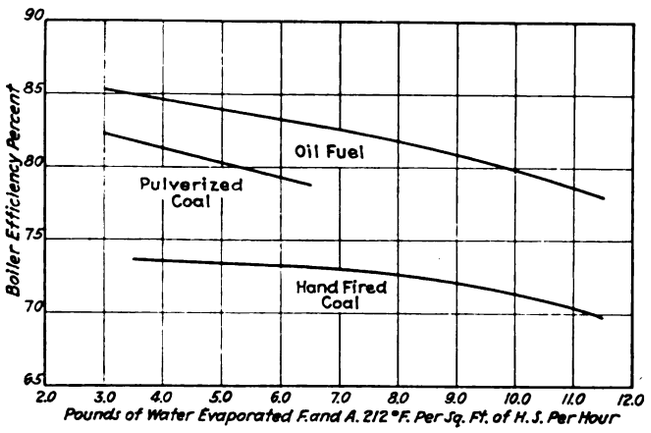

Fig. 8.—Curves showing comparative efficiencies using fuel oil, pulverized coal and hand fired coal

interfering with the operation of the burners. This was because of the compact nature of the fused ash compared to the porous and relatively large volume deposit secured with the high fusing ash.

Possibly complete water cooling of the furnace would assist in the matter of handling low fusing ash coals, but this is doubtful when one remembers how this slag acted on the bottom of the furnace row tubes. In a water-cooled furnace the deposit would probably build up on the water walls until sufficient depth was secured, so that any further deposits on them would remain plastic enough to run down the face of the walls to the floor. The water-cooled floor would gradually build up, the slag near the cooling tubes solidifying, the upper portion remaining in a partially plastic condition, depending upon its depth. Under these conditions, consideration might be given to tapping or skimming off the plastic material once a day from the top of the furnace floor. It is probable, however, that this procedure would not be as practicable on shipboard, where heavy seas may be encountered, as it is in some stationary plants where it has been entirely satisfactory.

From the above it may be concluded that, as long as coals having ash with fusing points higher than the furnace temperatures are used, no difficulty will be experienced with ash and slag deposits in the furnaces. If the ash content of the coal has a fusing point lower than the furnace temperatures, serious operating difficulties may be expected, whether the furnace is water cooled or not.

DUST AND POSSIBLE DANGER FROM SAME

Some people feel that the explosion and fire hazard from pulverized coal is so great that its application to ships is a somewhat doubtful procedure. We have not found that to be true, and our impressions are that, if proper precautions are taken, there is no more danger involved in using pulverized coal on shipboard than there is with oil. Certain "safety precautions" have to be taken with either of these fuels, and, if they are followed, the danger of explosion or fire is practically nil.

By using unit pulverizers an important step in the right direction will be taken, as this eliminates the necessity of carrying any stock of pulverized fuel, the fuel being burned with this system as fast as it comes from the mill.

As a pulverized coal burner cannot be shut off as readily by a man holding the lighting-off torch as can an oil burner, the action of the torch should be positive, otherwise a decided "puff" will occur in the furnace when the coal does finally catch.

For those interested in the safety phase of this problem, Bulletin No. 242, prepared by the Bureau of Mines and entitled "Explosion Hazards from the Use of Pulverized Coal at Industrial Plants," will be of value. It gives, in very complete form, experiences with this hazard and approved methods of overcoming the same.

EFFICIENCY

Consistently higher boiler efficiencies may be secured with pulverized coal, properly handled under a boiler, than with any other method of firing this fuel. We are fortunate in having directly comparable tests using oil, pulverized coal and hand-fired coal on this same boiler. Fig. 8 shows the efficiency curves secured with these three methods of firing, the upper curve showing results secured with three Babcock & Wilcox Cuyama type oil burners, the middle one the pulverized coal efficiencies taken from Fig. 5, and the lowest curve those secured with hand-fired coal.

In the case of oil firing, between ¾ and 1 percent of the steam generated by the boiler is used in getting the fuel to the furnace. The hand-fired coal requires none of the ship's power to deliver it to the furnaces. In the case of the pulverized coal, if a figure of 25 horsepower is used per 1,000 pounds of coal, and an average water rate of 30 pounds per horsepower is assumed for the auxiliary generator on the ship, then 750 pounds of steam are used per hour per 1,000 pounds of coal delivered to the furnace. On the average, 10 pounds of steam will be generated by 1 pound of coal or 10,000 pounds for the 1,000 pounds of coal.

$$\text{Accordingly } \frac{750}{10{,}000} \times 100 = 7.5 \text{ percent of the steam}$$

made by the boiler will be used to pulverize and blow the coal into the furnace. This more than cuts in half the *gross* difference in efficiency between the hand-fired and pulverized coal installations. If the water rate of the auxiliary generators is 60 pounds per horsepower (as is the case on a number of ships running at the present time) instead of 30 pounds, the *net* difference in efficiency between the hand-fired and pulverized coal installations will be in favor of the hand-fired one.

From the above, the importance of generating the auxiliary power efficiency on a ship using pulverized coal becomes evident; otherwise one of the desirable features of pulverized coal for ship work will be lost.

In a number of turbine electric installations the auxiliary power used at sea is obtained from the main unit, a standby auxiliary generator being used when the main unit slows below a certain point. Consideration is being given to a similar construction on turbine gear installations, a small generator being geared to the main unit when at sea. For a pulverized-coal ship, equipment of this type would be especially valuable as a shaft horsepower for auxiliary purposes could be generated for between 8 and 10 pounds of steam per hour in a moderately high pressure and superheat installation. Were this done, the steam required for pulverizing and blowing the coal into the furnaces would

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be relatively small and would be satisfactorily comparable with the results being secured in modern central stations.

FLEXIBILITY AND MANEUVERING

For quick maneuvering, a unit-mill pulverized-coal installation is not as flexible as oil. We are now conducting some tests to obtain complete information along these lines with both the Bonnot and the high-speed mill. In general,

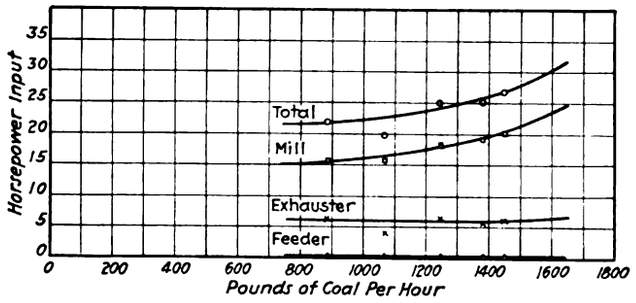

Fig. 9.—Curves showing horsepower input for high speed mill

there is no appreciable difference in the ability of the two mills from a maneuvering point of view. A steam-flow meter was used to determine the power output from the boiler.

For these tests marine maneuvering conditions were simulated; that is, the boiler operated from standby to one-half power to full power, noting the time required to attain these points. These tests consisted of operation with both pulverized coal and oil fuel. In general, with careful operation, maneuvering with pulverized coal requires twice the length of time required for oil. This careful operation means balancing the primary air with the quantity of coal fed to the mill. If this method is not followed, and the primary air becomes too great for the amount of coal fed to the mill, it will draw the coal from the mill to such an extent that the mixture becomes too lean and the flame goes out. Should this take place, the maneuvering will be seriously affected, and it will be necessary to relight the burners with a torch to prevent the possibility of a flareback when the mill is again producing at a satisfactory rate.

It is our impression that an installation may be so de-

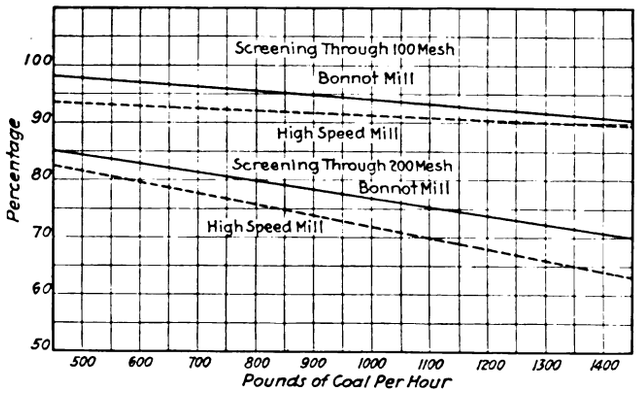

Fig. 10.—Curves showing fineness of coal, using (a) Bonnot mill, (b) high speed mill

signed that it will be a simple matter for the operator to keep the mill and exhauster in proper step with each other, and, in such an installation, the maneuvering will be no more of a problem than with any other type of installation.

It might be well to mention at this point that, in maneuvering with pulverized coal, it is not possible to shut off one or two burners, as is done with oil fuel. If this is attempted with a damper located in the individual pipes near the distributor head, then the coal and air which would have gone through the shut off burners will merely be diverted to the others remaining in service and there will be no appreciable change in the power output. In other words, maneuvering with pulverized coal is directly dependent upon maneuvering with a mill and exhauster and not with the burners themselves.

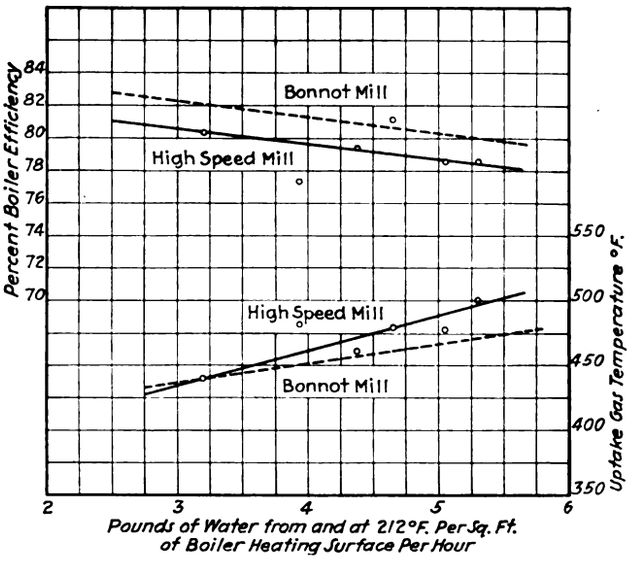
Percent Boiler Efficiency
Bonnot Mill
High Speed Mill
High Speed Mill
Bonnot Mill
Uptake Gas Temperature °F.
Pounds of Water from and at 212°F. Per Sq. Ft. of Boiler Heating Surface Per Hour

Fig. 11.—Comparative efficiency and uptake gas temperature curves using (a) Bonnot mill and (b) high speed mill

MILLS

The subject of mills is an extensive one, and this is not the place to discuss them at great length, but a couple of points that developed during the course of our experiments may be of interest. As previously noted, the tests shown in Table 1 were run with a No. 2, Fuller-Bonnot unit mill, which is of the ball type. As the bulk and weight of this

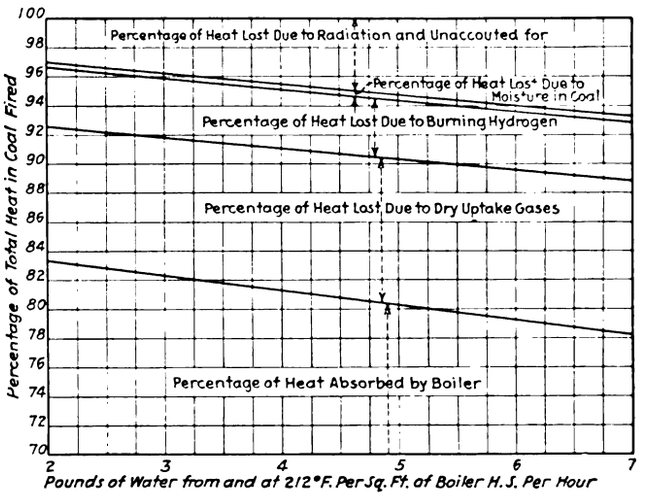
Percentage of Heat Lost Due to Radiation and Unaccouted for
Percentage of Heat Lost Due to Moisture in Coal
Percentage of Heat Lost Due to Burning Hydrogen
Percentage of Heat Lost Due to Dry Uptake Gases
Percentage of Heat Absorbed by Boiler
Percentage of Total Heat in Coal Fired
Pounds of Water from and at 212°F. Per Sq. Ft. of Boiler H. S. Per Hour

Fig. 12.—Curves showing heat balance, using high speed mill

type of mill are a disadvantage for marine purposes, a mill of the high-speed, impact type was installed and tests conducted with it. The comparison between the mills was made with all other equipment, as well as coal, remaining the same, the only change being in the shift from one mill to the other. The commercial rating of both mills was the same, 2,000 pounds of coal per hour.

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Fig. 9 shows the power requirements for the high-speed mill, these curves being directly comparable with Fig. 3 for the Bonnot mill. The feeder of the high-speed mill was operated with a separate motor, which accounts for the lowermost curve on Fig. 9.

Fig. 10 gives a direct comparison of the grinding qualities of the two mills. The Bonnot produced the finer coal at all rates, this being especially true through the 200-mesh screen. Although the total power requirements for the high-speed mill are less for a given coal output than for the Bonnot, when the fineness of coal is used as a basis, there is very little difference between them.

The most interesting comparison between the two mills was in the boiler efficiencies, this being shown in the upper portion of Fig. 11. As may be noted from the lower portion of this plate, some of the difference in efficiency secured was due to the higher uptake gas temperatures obtained with the high-speed mill, the CO_2 being the same in both cases.

To indicate more clearly the causes of the improved efficiencies secured with the Bonot mill, Fig. 12 has been prepared to show the heat balances secured during the high-speed mill tests. This may be directly compared with Fig. 7 showing corresponding heat balances secured with the Bonnot mill. A comparison of these two plates shows that, although the increased heat carried away by the uptake gases during the high-speed mill tests accounted for a portion of the difference in efficiency, the principal cause of the difference was in the unaccounted for and radiation losses.

This brings up the effect of the fineness of the grind of the coal on boiler efficiency, as being a very important point in small, pulverized-coal marine furnaces. It would undoubtedly be well to devote further research to determine the best *commercial* fineness for use on ships. This will involve a study of the increased fineness and additional power required to produce the same, balanced against the increased boiler efficiency resulting.

As may be noted in the heat balance curves (Figs. 7 and 12), the radiation and unaccounted for losses increase with rating of the boiler, a condition which would not exist if the combustion were uniformly efficient at all rates. Just how much of this increased loss is due to the coarser coal is an important point to be determined, and one which will of necessity be looked into as the art progresses.

Another interesting point that developed between the two mills using the same coal (Dundon gas slack) was the fact that, at about 1,200 pounds of coal an hour and 13½ percent CO_2 the high-speed mill runs gave as much trouble from slag at the bottom row tubes (closing over the same) as the Bonnot mill did at about 1,500 pounds per hour and 15 percent CO_2. This would indicate that increased fineness of grind of the coal will not only improve the efficiency but will also reduce the tendency of the ash to bridge across and close the gas opening at the bottom of the first pass of the boiler.

From an operating and upkeep point of view, our experience would incline us to strongly favor the ball type of mill for marine installations in spite of its increased weight and bulk compared to the high-speed mills. During the months we had it in operation it gave no trouble of any kind, and we never lost a minute of our testing time because of the mill.

One characteristic of pulverized-coal unit-mill installations which operators should have in mind, when contemplating their use, is the minimum point of operation of the mill. By minimum point is meant the capacity of the mill below which no coal may be secured from the same. With the mills at Bayonne the lowest point at which we could keep the burners in operation was about 400 pounds per hour. With larger mills this point would, of course, move up correspondingly. If in port it is necessary to burn coal at lower rates than the minimum mill capacity, it will be necessary to shut down and light up burners as required.

The moisture content of the coal as fed to a mill has an appreciable effect upon the capacity of the same, the greater the moisture the less the capacity. The temperature of the air entering the mill is also an important factor in mill capacity when the coal is moist. We did not run any tests to obtain comparative information along these lines at Bayonne, but it would be well to keep in mind that the drier the coal and the hotter the intake air to the mill, the better the capacity of the mill will be.

All coal coming to a mill, regardless of the type, should be in sizes of 1½ inches or less. If, in the ships regular run, coal of this size is not assured at the pier, it will be necessary to install a crusher on the ship. This may be located so as to crush the coal as it comes into the bunkers, or, what would be preferable in the average ship, crush it just before it reaches the mill. A crusher of this kind could also be so designed as to remove any tramp iron that might be in the coal. In the case of ball mills, removal of this tramp iron is not necessary; in the case of impact or hammer mills, it is very desirable.

CONCLUSIONS

1. If proper care is taken in the design of the burners, pulverized coal may be burned efficiently at the high combustion rates necessary under marine boilers when the furnace volume is small in relation to the heating surface.
2. The fusing point of the ash in the coal should be above the average flame temperature, or the resulting ash in the furnace and on the tubes will be a source of shutdown.
3. To obtain the full benefit in efficiency from burning pulverized coal, the auxiliary power in the ship should be generated in the most efficient manner possible.
4. When used with watertube boilers, pulverized coal installations do not need oil as an auxiliary fuel.
5. Because of their dependability and improved quality of the coal output, ball mills are to be preferred to the impact or hammer type for marine purposes.
6. In general, there is no reason why pulverized coal should not be used aboard ships provided certain precautions are taken to insure safety, dependability, convenience of operation and reasonably high overall efficiency.

Small Turbine for Pulverized Fuel

AMONG other equipment developed for use in pulverized coal-burning marine installations, the marine department of the Terry Steam Turbine Company, which is conducted by the Kearfott Engineering Company, Inc., 117 Liberty street, New York, has announced a self-contained, light weight, geared turbine unit, which is adapted for driving pulverizers, fans and other auxiliaries. This turbine is built in sizes from 5 horsepower to 40 horsepower and has been used extensively and successfully with boiler room equipment.

The turbine is suitable for high steam pressures and superheat, and because of the special design of the governor, the company states that high efficiency can be maintained for all operating conditions. The throat area of the governing valve is varied with load requirements, making it possible to maintain constant nozzle pressures.

Speed range is obtained by means of an oil governor, which functions as a variable speed control, an over-speed shut-off and a no-oil stop. Forced feed lubrication is used throughout, being provided by a gear pump driven by the worm wheel shaft through noiseless gears. An oil spray is forced against the worm wheel shaft and worm at the

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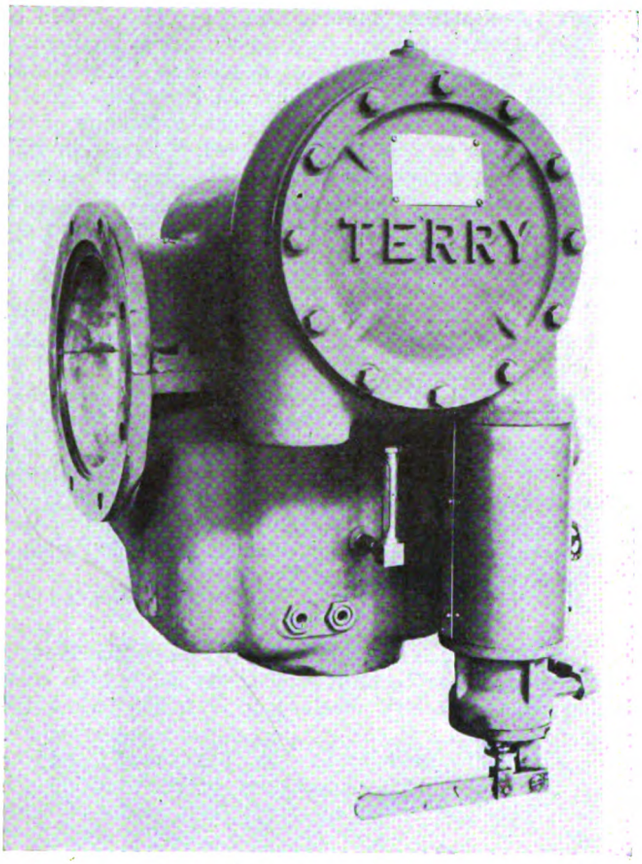
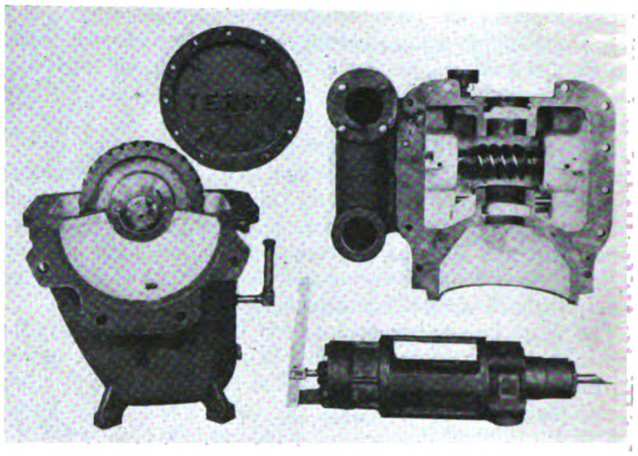


Compact, self-contained geared turbine unit for driving auxiliaries

point of contact, making it possible to have the oil level at all times below the worm wheel, which eliminates any churning action and unnecessary heating of the oil. A large reservoir is provided with an oil cooler for maintaining the temperature at a low minimum.

The worm wheel reduction ratio is selected to give the best operating speed to meet any given requirements. The worm, which is located on top of the worm wheel, also forms the turbine shaft and is made of steel alloy. The



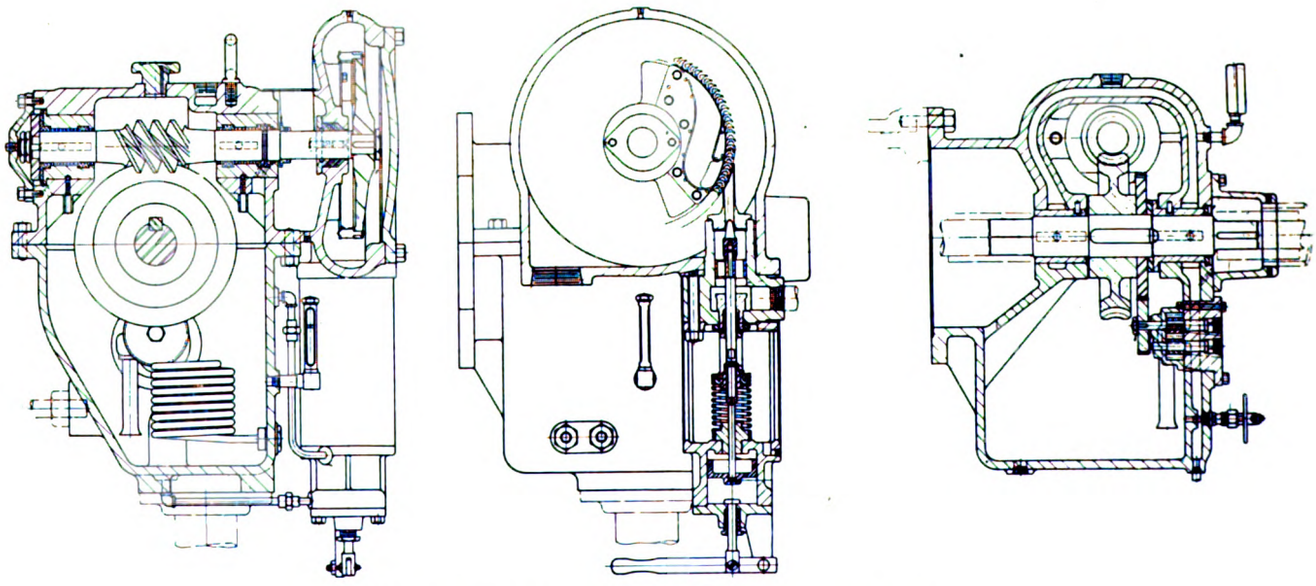
Assembly parts of Terry turbine

worm wheel itself is made of phosphorized Virgin Straits tin and Virgin Lake copper.

To provide for the high speeds involved and the nature of the drive, high grade tin base babbit bearings are provided. These bearings have a certain amount of resilience, which is highly essential for the speeds and loads to which bearings for this type of drive are subjected.

Shipping Board to Sell Pacific Lines

THE Shipping Board voted on November 29 to advertise for bids for the purchase by private American interests of its remaining lines on the Pacific. Two alternate methods of bidding are specified. Under one, the terms are to be 25 percent cash and the balance in 10 equal annual installments with interest at 4¼ percent per annum, the purchaser guaranteeing to maintain the present services with no interchange of ports for e period of 5 years. Under the second plan, the terms are 10 percent cash, the balance to be paid in equal annual installments at 4¼ percent interest, spread over 10 or 15 years, the bidder is to agree to maintain the line or lines without interchange of ports as presently operated for a period of 3 years with an option to transfer the ships back to the Government at the end of the period.



Sections through casing of small geared turbine unit

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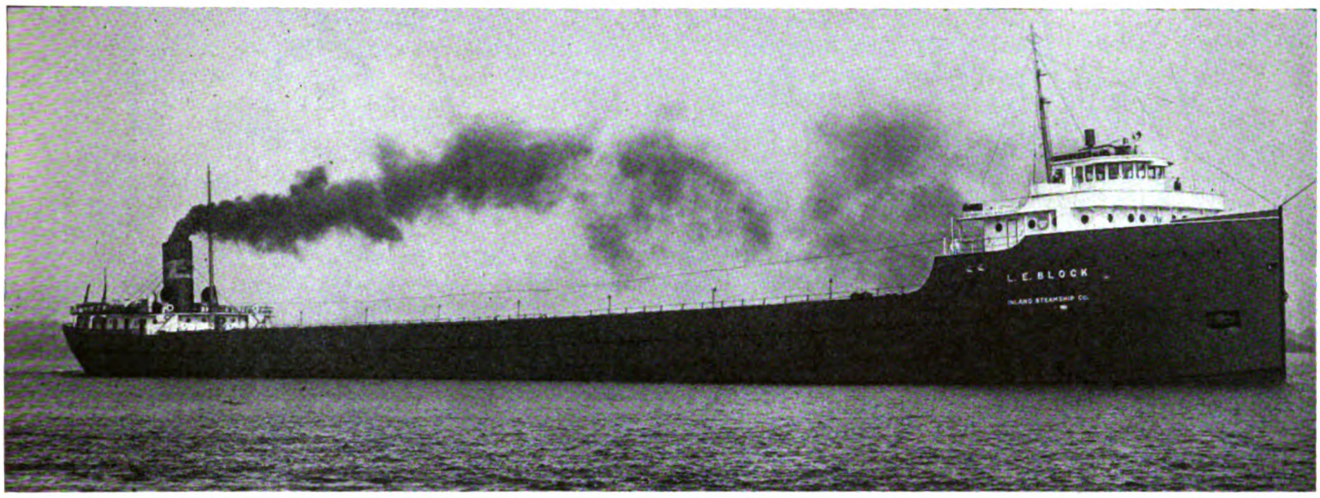

Bulk freight steamer L. E. Block: Deadweight capacity, 13,500 tons; indicated horsepower, 2,800

Great Lakes Bulk Freighter L. E. Block

Built by The American Ship Building Company for The Inland Steamship Company—Deadweight capacity, 13,500 tons

ONE of the latest additions to the large fleet of bulk freight steamers on the Great Lakes is the *L. E. Block,* built by The American Ship Building Company at their Lorain, Ohio, yard for The Inland Steamship Company of Chicago, Illinois.

This vessel is built to Lloyd's Register of Shipping highest class for service on the Great Lakes. She is considerably larger than the usual standard and is of the following dimensions:

Length overall	620 feet 9 inches
Length between perpendiculars	596 feet 0 inches
Beam molded	64 feet 0 inches
Depth molded	33 feet 0 inches
Mean draft	20 feet
Deadweight capacity on 20-foot draft	13,500 tons
Indicated horsepower	2,800

As shown on the plans, this steamer is built on the transverse system on sides and on the longitudinal system on the bottom. She has 18 cargo hatches spaced 24 feet between centers, 41 feet 6 inches wide in the clear, 47 feet 6 inches wide inside of the coamings and 12 feet wide fore and aft. Sliding steel covers are provided operating from steam hatch engines with wire line and bridles. Her hold is divided into three compartments with a blind hold fitted at the forward end.

Hopper bottoms are fitted in the coal bunker which has a capacity of 513 tons. Side hoppers extend the full length of the cargo space and form part of the water ballast space. There is a total capacity of 9,496 tons of water in the side tanks, double bottoms and peaks. Her cargo holds have a capacity self-trimmed of 575,766 cubic feet, or 462,916 bushels. She has a deadweight capacity of 13,500 tons on a mean draft of 20 feet.

General Arrangement

The cabin arrangement shows the engineers quarters located at the forward end of the after deck house. Quarters for the stewards, oilers, coal passers, firemen and the crew's sitting room are on the starboard side and for the porters, galley, pantry, storeroom, cold storage and private dining room are on the port side of this house with the officers' dining room on the center at the after end with an entrance to a stairway to the engine room alongside. The engineer's store room, laundry, toilets, steering engine and refrigerating machinery are on the deck below.

The forecastle contains accommodations for the mates, wheelsmen, watchmen, deck hands, store room and crew's sitting room with a dunnage room below. The windlass room is in the forward end of the forecastle.

A large texas is provided on the forecastle deck containing the captain's quarters and two staterooms with bath and sitting room for the owners.

The pilot house is equipped with a docking and engine room telegraph, electric whistle, radio direction finder, Sperry gyro pilot and compasses and the usual whistle pulls and indicators.

Propelling Machinery

The propelling power for this steamer is provided by a triple expansion engine, with cylinders 25½, 41 and 67 inches in diameter by 42 inches stroke. The low pressure cylinder is forward, the high pressure in the center and the the intermediate aft. The high pressure cylinder has a piston valve, while the intermediate and low pressure cylinders have double ported slide valves, all driven by the Stevenson valve gear of the overhung type, common to the lakes. The intermediate and lower pressure valve gears are carried by Lovekin assistant cylinders to overcome their weight and inertia.

The engine is designed to use steam at 185 pounds per square inch pressure. The ratio of the cylinders from high pressure to low is 1:2.56:6.9. With a cut-off of 75 percent the number of expansions is 9.2. The indicated horsepower developed at 95 revolutions per minute is about 2,800.

The back columns, three in number, carry the guides which are water cooled. The front columns, four in number, carry the reverse and rock shaft and give easy access to the engine and bearings.

The crank shaft is of the built-up type. The crank slabs are of the same open hearth steel as the shaft, which is to Lloyd's specifications, as is all of the machinery.

The thrust shaft has seven collars and is run in an oil

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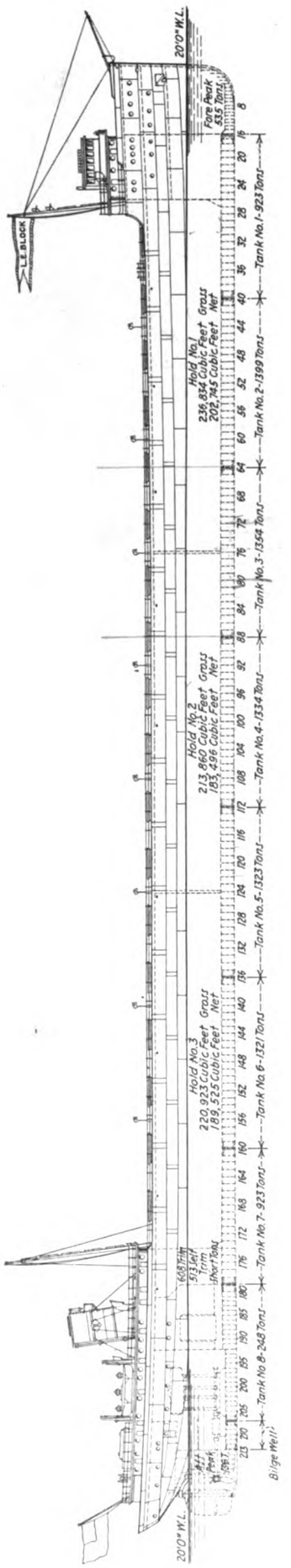
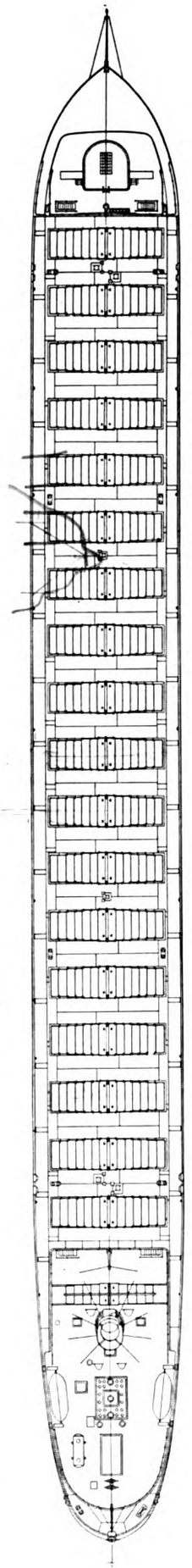
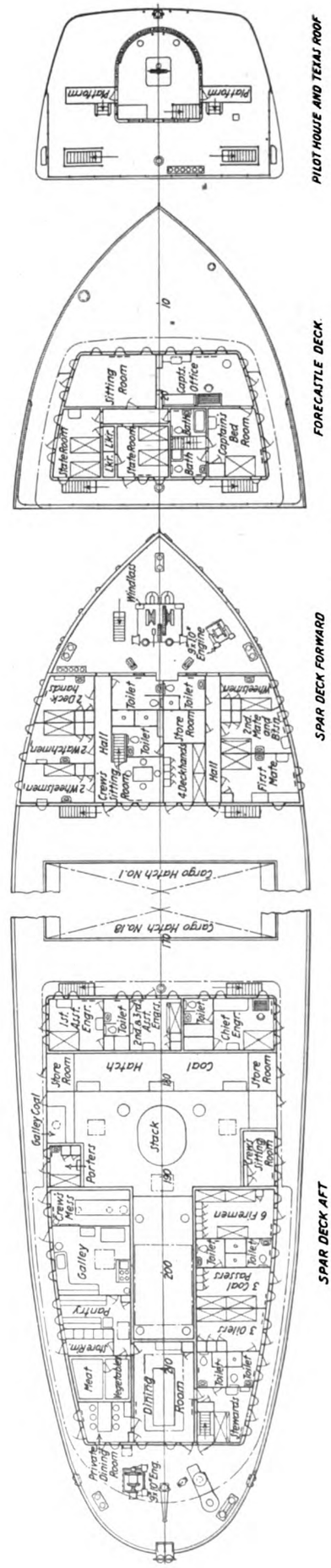




Profile and deck plan of the Inland Steamship Company's new bulk freighter L. E. Block



Arrangement of accommodations on the bulk freighter L. E. Block

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bath, water cooled. The horseshoe collars are cooled in their center core and are under about 50 pounds pressure, provided by a special lubricating pump.

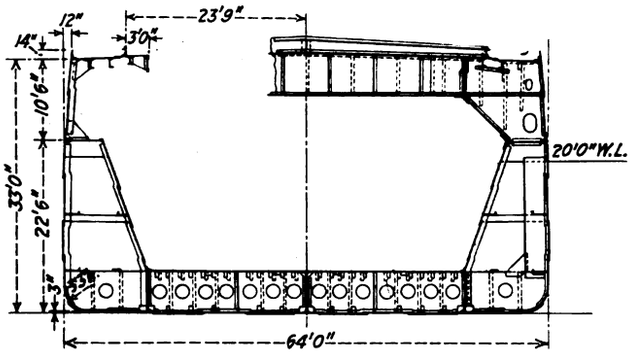
The stern tube is of the usual funnel shape at the forward end to provide for the easy renewal of the tail shaft.

The propeller is of cast steel 15 feet 3 inches in diameter by 14 feet 9 inches pitch. The surface is all ground smooth.

The connecting rods are 9 feet long between centers, with wedge adjustment at the top and regular bolted connections at the bottom. The bearings are of cast steel.

The pistons are all of cast iron box section provided with the usual piston ring packing. The piston rods, which are made of the finest high grade carbon steel, and the valve stems are all fitted with C. Lee Cook metallic packing. The crossheads are of cast steel and the pins of special high carbon steel.

The main bed plate is of the girder type, fitted with



Midship section

four bearings of the square box type. The lower half has a removable steel circular bearing filled with white metal.

Attached to the engine is an Edwards air pump and jet condenser with auxiliary Wheeler air jets for port service only.

Steam is supplied at 185 pounds per square inch by three Scotch boilers, 14 feet 6 inches in diameter and 11 feet long over the heads. Each boiler is fitted with two 54-inch inside diameter Morison suspension furnaces,. The total heating surface of the boilers is 8,079 square feet.

The Ellis and Eaves system of heated air is used, the temperature at the base of the stack being normally 400 degrees Fahrenheit.

Foster superheaters are installed in the air heaters giving a superheat of 60 degrees Fahrenheit. The piping is arranged so that the auxiliary machinery can be used under superheated or saturated steam, as may be desired.

Brews mechanical soot blowers are fitted to all boilers and air heaters and superheaters. Three Learmouth vertical purifiers are provided for purifying the boiler feed water.

BALLAST SYSTEM

The ballast piping is 8 inches in diameter. The pipes are connected to a double manifold in the engine room and are so arranged that the contents of any tank can be pumped out, or pumped from one tank into any other. Two 15-inch Morris centrifugal pumps, direct driven by vertical high speed engines with cylinders 8 and 14 inches diameter by 10 inches stroke, take the main body of water, delivering 8,000 gallons each at 275 revolutions per minute. Two horizontal duplex Warren pumps, 10 inches by 14 inches by 16 inches, can also be used on the tanks and also for drainage.

The sanitary system is connected to two 4,500-gallon raw water storage tanks located in the dark hold forward and connected to a horizontal duplex 6-inch by 4-inch by 6-inch sanitary pump which discharges water, both hot and cold, at 40 pounds pressure, to all basins, bath tubs, etc., throughout the ship.

Drinking water is supplied from a Davis Engineering Company's evaporator and still and forced by a 3-inch by 2-inch by 3-inch duplex pump to a large storage tank aft on the house and to the galley and to drinking fountains piped through a refrigerator tank meeting the highest requirements of United States Health Department regulations.

The electrical plant consists of three Crocker Wheeler generators, two of 15 kilowatts and one of 10 kilowatts capacity driven by American Blower vertical engines.

The feed water heater is of the Griscom Russell vertical type located on the bulkhead in the boiler room.

DECK MACHINERY

The main windlass is of the American Ship Building Company spur gear type, all gears being of steel and machine cut. Wildcats are provided for 2¼-inch cast steel chain made by the National Malleable Castings Company.

Six 9-inch by 10-inch horizontal deck engines, made by the American Ship Building Company, are provided, one in the windlass room, four on deck and one located aft on the fan tail, with a winch head for auxiliary steering attachment to the tiller.

The deck machinery also includes a 9-inch by 9-inch American Ship Building Company direct geared steering engine with cast steel quadrant in two sections and interchangeable rack gears all machine cut. A steering engine control shaft 1 7/16 inches in diameter is carried from aft forward through Hyatt roller bearings run in grease to the wheel stand, which can be connected at will to the "Metal Mike."

AUXILIARIES

The complete list of auxiliaries is tabulated as follows:

2 Warren horizontal duplex, auxiliary ballast pumps, 10 by 14 by 16 inches.
2 Morris 15-inch centrifugal main ballast pumps, connected to 8 by 14 by 10-inch compound engines.
1 Wheeler 6-inch centrifugal tail pump, turbine driven.
1 Warren horizontal simplex main feed pump, 14 by 8½ by 16 inches.
1 Warren horizontal duplex auxiliary feed pump, 12 by 6 by 12 inches.
1 Warren horizontal duplex mates pump, 7½ by 5 by 8 inches.
1 Warren horizontal duplex sanitary pump, 6 by 4 by 6 inches.
1 Warren horizontal duplex water service pump, 5¼ by 4¾ by 5 inches.
1 Warren horizontal duplex drinking water pump, 3 by 2 by 3 inches.
1 Warren horizontal duplex oil (thrust) pump, 4½ by 2¾ by 4 inches.
2 Crocker-Wheeler 15-kilowatt generators, connected to 6-inch by 6-inch American Blower steam engines.
1 Crocker-Wheeler 10-kilowatt generator, connected to 5-inch by 5-inch American Blower steam engine.
1 Griscom-Russell vertical feed water heater.
1 Davis Engineering Corporation, 50-gallon per hour, feed water distiller.
1 Union Steam Pump horizontal simplex condensate pump for auxiliary condenser, 4 by 6 by 5 inches.
2 Wheeler single stage jet air pumps for main condenser.
1 American Ship Building Company vertical attached bilge pump, 5¾ by 13¼ inches.
1 American Ship Building Company vertical attached cooler pump, 5¾ by 13¼ inches.
1 American Ship Building Company vertical jet condenser, 36 inches diameter of barrel.
1 American Ship Building Company vertical attached air pump, Edwards' type, 37 by 15 inches.
1 American Ship Building Company auxiliary vertical jet condenser, for exhaust from forward.
3 American Ship Building Company vertical feed purifiers, 42 inches by 9 feet.
1 Brunswick-Kroeschell 2-ton refrigerating machine driven by single cylinder vertical steam engine.

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1 Conveyors Corporation of America 6-inch nozzle steam and water ash conveyor.
2 American Ship Building Company type "E" hatch engines, 6 by 6 inches.
5 American Ship Building Company type "A" deck engines, 9 inches by 10 inches, single drum.
1 American Ship Building Company type "B" deck engine, 9 by 10 inches, single drum with gypsey.
1 American Ship Building Company spur geared windlass, 10 by 10 inches, 2¼-inch chain.
1 American Ship Building Company "D-A" steering engine, 9 by 9 inches.
1 American Ship Building vertical duplex fan engine, 6 by 5 inches.
1 American Ship Building Company built-in turning engine, 4½ by 5 inches, duplex vertical.
1 American Ship Building Company vertical attached reverse engine 12 by 21 inches, on main engine column.
3 Foster built-in superheaters.

South American Cargo and Passenger Motorships

Eight similar European-built vessels for the Costeira Company and the Lloyd Nacional of Brazil

By Our Special London Correspondent

CONSIDERABLE interest was evinced in European shipbuilding circles a year or two back when it became known that the two prominent Brazilian shipping companies of Rio de Janeiro, the Costeira Company and the Lloyd Nacional, were about to place orders for a number of ships of about 5,000 tons gross, to have substantial passenger accommodation and to be engaged on the coastal service of South America.

All the ships engaged in that trade have hitherto been steamers, but after an examination of the problem, both companies came to the conclusion that motor craft would prove advantageous and it was decided to build eight oil-engined craft, four for each of the firms mentioned.

The orders were split up and while the four ships for the Lloyd Nacional were contracted in Italy, the Costeira Company ordered three ships from Beardmores on the Clyde, and one from the Chautier et Atelier de St. Nazaire, in France.

The demands for the ships for the two companies are somewhat different and the passenger accommodation is arranged on a more substantial scale in the Costeira Company's vessels, although the speeds of all the ships are the same, and the hull dimensions differ only in a very small degree. The first of the Costeira Company's vessels, the *Itapé*, ran trials on the Clyde at the beginning of November while the first of the Lloyd Nacional's ships, the *Araranguá*, was completed a month or two back.

As may be imagined, these craft are of somewhat special type and not only in the hull design and passenger accommodation are certain unusual features introduced, but the machinery has points of novelty which are worth recording.

The *Itapé* and her three sister ships, which are named *Itapagé*, *Itanagé* and *Itaquicé*, is 370 feet in length, with a beam of 52 feet, and a depth of 26 feet 9 inches, her gross tonnage being 4,900 and the mean loaded draft 20 feet 6 inches.

The accommodation is for 145 first class passengers, 40 intermediate class passengers and 90 third class passengers, all in cabins. Altogether, there are 49 first class cabins but these include the two cabins de luxe. In addition to general cargo, one of the holds is fitted out for the carriage of salt, while there is refrigerated space to the extent of about 20,000 cubic feet.

A feature which is rather unusual and which, failing some special reason which appears rather difficult to justify, is the employment of steam-driven cranes on deck for handling cargo. There are 10 of these, eight capable of lifting 30 hundredweight and the remaining two 3 tons. Part of the remaining deck machinery is steam driven and part electrically operated, the latter section including the steering gear. No doubt the adoption of a certain number of steam auxiliaries was due to the lower cost, but they will certainly be more expensive to operate than electrically driven plant.

Engines with Superchargers

There is undoubtedly a developing tendency in Europe to employ electrically operated superchargers on motorships, with the object of increasing the speed of the vessel to a certain extent, say half a knot to a knot, if necessity arises. The *Itapé* is a case in point, and it is arranged that, whereas normally she will run with unsupercharged engines, if a slightly higher speed is needed on occasions, the supercharging blowers will be brought into operation. The increase in power that can be attained by this means is about 10 percent and it is obviously a reserve that may come in very useful at times.

There are two engines and it is intended to maintain 14½ knots at sea in normal circumstances when fully laden. These units are of the Beardmore-Tosi four cycle, single acting type of which only comparatively few have hitherto been placed in service. Their distinguishing feature is the adoption of what is termed a director valve in each cylinder. This, alternately, places first, the exhaust pipe, and then the air induction pipe, in communication with the cylinder through a common valve which is used both for air admission and exhaust. Actually, in the engines of the *Itapé*, the common valve is duplicated, but this is merely to reduce its diameter and not because of necessity from other standpoints.

The advantage which is claimed with this system is that as cool air passes over the valve, every two revolutions, these valves are always kept clean so that the necessity for overhauling the exhaust valves, as in the usual four cycle engines, is avoided. Many engineers appear to doubt whether this characteristic is of sufficient value to warrant what is apparently an added complication, but it is to be remarked that with some examples of the Werkspoor double acting engine, a somewhat analogous principle has been employed.

The two motors in the *Itapé* have six cylinders with a diameter of 26 inches and a piston stroke of 43¼ inches. Each develops about 1,800 brake horsepower when running at 120 revolutions per minute and, as already mentioned, in order that higher power can be obtained in case of necessity, supercharging is employed. By this means, the output of each unit can be raised to nearly 2,000 brake horsepower. The utilization of electrically driven superchargers supplying air to the working cylinders under slight pressure is now becoming more common in Europe, but this is the

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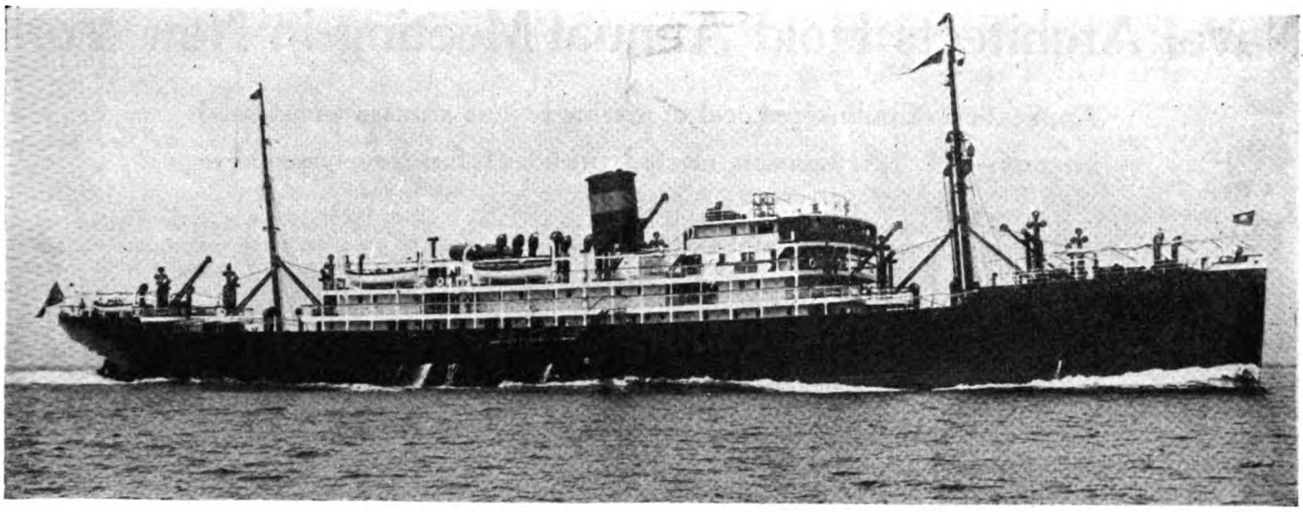

The cargo and passenger motorship Ararangua

largest supercharged installation that has yet been constructed in Great Britain where the system has not been received with such favor as on the Continent.

One of the four vessels of this group is being built at the Chantier et Atelier de St. Nazaire, St. Nazaire, France, and will shortly go on trial, having been launched in July, 1926. The only difference is that Burmeister and Wain type engines are to be installed, two 6-cylinder 1,800 brake horsepower units being fitted. They have cylinders 630 millimeters bore, with a piston stroke of 1,100 millimeters and run at 140 revolutions per minute. In this case also supercharging is utilized in order to raise the power when necessary.

Turning now to the four vessels for the Lloyd Nacional, it will be found that their dimensions are practically identical with the Costeira Company's ships. The first of the former, the *Ararangua,* has already gone into service, and the remaining three will probably be completed within the course of the next few months. The main dimensions are as under:

Length between perpendiculars	370 feet	
Molded beam	53 feet	6 inches
Depth to upper deck	27 feet	4 inches
Loaded draft	18 feet	
Gross tonnage	4,900	

The draft is slightly smaller, but the speed remains the same, namely 14½ knots.

The general layout of the vessels is somewhat similar, the lines being alost identical, but only one class of passengers is carried, the total number being approximately 100. They are mainly berthed in cabins for four passengers, and the accommodation is on nothing like so luxurious a scale as in the *Itapé* and her sister vessels.

The propelling machinery is of an entirely different class and takes the form of twin screw Fiat single acting Diesel motors. Each engine is designed to develop from 1,750 to 2,100 brake horsepower, the maximum speed being about 130 revolutions per minute. They are self-contained, with their own air compressors and scavenging pumps. Automatic valves are fitted for the admission of scavenging air to the working cylinders.

Whereas in the *Itapé* and the similar vessels, steam driven machinery is largely utilized, and there are steam cranes on deck, in the *Ararangua* the more modern method of utilizing electrical auxiliaries is adopted.

In the engine room, there are three Diesel driven generators of 150 brake horsepower and practically all the auxiliary plant is driven by electric motors, although cargo is handled by hydraulic cranes served by electrically operated pumps in the engine room. A Cochran oil-fired boiler is installed merely for heating and other minor purposes, but the refrigerated machinery is electrically driven.

All the eight ships are provided with a steamer funnel and in profile their resemblance is most marked. The result achieved with their operation will, no doubt, go far to determine the future type of ship to be utilized in the important South American coastal services, and for this reason, if for no other, the vessels may be considered as having a particular interest to owners.

Second Atlantic Refining Motor Tanker Goes in Service

THE *Sharon,* Diesel-electric tanker for some time under process of conversion for the Atlantic Refining Company, was given its trials during the week ending October 22. This is the second of the three conversions to Diesel-electric drive which has been completed for the Atlantic Refining Company, the first boat, the *Point Breeze,* having recently returned from its maiden voyage to Europe.

The three boats were purchased from the United States Shipping Board and the drive was changed over under the personal supervision of L. M. Goldsmith, technical engineer of the Atlantic Refining Company. The *Point Breeze,* first to go in service, was reconditioned by that company at its Point Breeze plant, while the *Sharon* and the *Bessemer* were converted by the Alabama Dry Dock & Ship building Company at Mobile, Alabama.

All three boats will probably be operated in coastwise service, but may occasionally be used in foreign service between American ports and South Africa or Europe. They were formerly propelled by steam machinery, but the new power plants consist of Ingersoll-Rand Diesel engines and electric equipment furnished by the General Electric Company. Each tanker is equipped with three 850 horsepower 225 revolutions per minute, Diesel engines, each driving a 525-kilowatt, 250-volt generator for propulsion and a 50-kilowatt, 250-volt auxiliary generator for excitation and ship's auxiliary power. The propulsion generators supply power to an 1,800 horsepower, 90 revolutions per minute, 750-volt, double motor on each vessel, direct connected to the propeller shaft. The control is of the variable voltage type arranged for operation either from the pilot house or the engine room, the control panels being of the dead-front type.

The tankers are fitted with electric auxiliaries all of which are driven by General Electric motors.

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Naval Architects Hold Annual Meeting in New York

Application of pulverized coal in marine boilers arouses widespread interest — H. L. Ferguson elected president for three-year term

THE annual meeting of the Society of Naval Architects and Marine Engineers, which was held on November 10 and 11 in the auditorium at the Engineering Societies Building, 29 West 39th street, New York, aroused unusual attention because of the discussion of papers relating to the use of pulverized coal in Scotch and marine watertube boilers and also because of the unusual number of papers devoted to the application of Diesel engines to marine propulsion. The program was divided into two parts, the papers presented on the first day being of a general nature while the entire program of the second day was taken up with the discussion of pulverized fuel and Diesel engines.

Rear Admiral D. W. Taylor, U. S. N., Retired, president of the society, presided at the meetings. Homer L. Ferguson, president of the Newport News Shipbuilding and Dry Dock Company, was unanimously elected president of the society for a term of 3 years beginning January 1, 1928.

At the opening of the meeting the president, in the absence of D. H. Cox, secretary-treasurer of the society, presented the report of the secretary-treasurer, which showed a total membership of the society on October 21, 1927, of 1,346 as against 1,370 a year ago. The report reported the deaths of 17 members and the resignations of 24. The financial statement showed the total resources of the society as $108,162.84, of which $83,932.81 comprises the endowment fund.

Resolutions

Resolutions relating to the death of Rear Admiral Francis T. Bowles, past president of the society, were read in part as follows:

Rear Admiral Francis T. Bowles

That the death of the society's second president, the late Rear Admiral Francis Tiffany Bowles, has removed from our midst one of our most distinguished members, to whom the society owes a special debt of gratitude for his conspicuous service in connection with its foundation and development.

That in his long and unusually active and brilliant career in the service of his country and in highly important executive positions in civil life he exhibited rare qualities of leadership and professional ability, his mature experience and great ability being always at the service of our society, whose development and best interests were always dear to him.

That we extend to his family our profound sympathy in their irreparable loss, realizing as we do the great sorrow which must inevitably follow the passing of such a devoted husband and father, whose compelling personality and unusual qualities of heart and mind made a lasting impress upon all who were privileged to call him friend and so fortunate as to experience those associations with him which brought out in fullest relief the most truly personal and sympathetic side of an unusually gifted man and loyal friend.

That the foregoing be published in the society's *Transactions* and that a suitably engrossed copy be sent to the family of our late past president.

Memorials relating to the deaths of Rear Admiral Bowles and Warren T. Berry were also read by Captain Walter M. MacFarland, past president of the society. The following resolution was then unanimously adopted in response to an invitation from Senator Jones asking for the opinion of the society regarding measures which he had presented to Congress:

The shipbuilding facilities are now at a very low ebb, owing to lack of business, due to the partial disarmament treaties with other leading nations, to the surplusage of merchant tonnage incidental to the Great War, and to other well known causes. Of all the great plants which built the enormous fleets for the Government to help win the war, only six now remain capable of building ships of major size. By far the greatest blow to the industry has been the inevitable alienation of the trained personnel into other pursuits. Without wishing to cause undue alarm, we feel constrained to state that our shipbuilding facilities are now at a lower point than they were prior to 1914, and that they are now in a condition which places this country in real danger, both from the standpoint of commercial efficiency, and from that of our national defense in time of war.

We would emphasize that the foregoing statements are not made in the hope or expectation that they will arouse sympathy and help for the industry. Alas, we who have spent our lives in it have, during recent years, seen so many adverse conditions arise that we have almost lost hope. It is not that nothing is being done, but that, in spite of repeated advice from the experienced leaders of the industry, the efforts are misguided and ill-advised. The expenditure of a large amount of Government money is accomplishing nothing of permanent benefit, while a smaller sum, properly applied, would give us a successful merchant marine, flourishing shipyards, and highly trained personnel —all a most valuable asset to the country.

Our warning to those in authority, and who only can remedy the existing distress and decadence of the shipping industry, is made as a patriotic duty, and to impress upon them the catastrophe which awaits our country if this great industry is not encouraged and revivified.

We believe, in general, that criticism to be of any value should be constructive. As already stated, competent advice has been offered to those in authority, but without avail. Under such circumstances we cannot see that any benefit would result from a renewal of this advice. We do say, however, that when the authorities wake up to the critical condition of the shipping industry, and ask us, as the leading representatives of that industry, for help and advice in the enactment of constructive legislation, we shall, as patriotic citizens, respond with our whole-hearted cooperation.

Election of Officers

The following officers were elected to fill vacancies:

President: Homer L. Ferguson.

Honorary members: Washington L. Capps, Walter M. MacFarland, David W. Taylor.

Honorary associate: Robert M. Thompson.

Honorary vice-president: Albert P. Niblack.

Vice-presidents (term expiring December 31, 1930): Hutchinson I. Cone, Joseph W. Powell, Charles F. Bailey, Samuel W. Wakeman.

Vice-president (term expiring December 31, 1929): Charles A. McAllister, vice Homer L. Ferguson.

Vice-president (term expiring December 31, 1928): J. Howland Gardner, vice A. P. Niblack.

Council members representing members (term expiring December 31, 1930): Richard H. M. Robinson, Emory S. Land, J. H. Mull, Robert Haig, Charles W. Dyson, John Halligan, Jr.

Council members representing members (term expiring December 31, 1928): Elmer A. Sperry, vice C. A. McAllister; William W. Smith, vice J. Howland Gardner.

Council members representing associates (term expiring December 31, 1928): Charles M. Wales, Ira A. Campbell, Philip A. S. Franklin.

Executive committee: Washington L. Capps, Walter M. MacFarland, Francis L. DuBosque, Joseph W. Powell, J. Howland Gardner, Charles A. McAllister, Morris D. Ferris.

Secretary-Treasurer: Daniel H. Cox.

Assistant Secretary-Treasurer: Thomas J. Kain.

Ninety-one new members were elected to the society, 68 of whom were members, 11 associates and 12 juniors.

In delivering his annual presidential address Admiral Taylor reviewed the situation in the shipbuilding and shipping industries in part as follows:

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The President's Address

For the third successive year it is my painful duty to remark upon the unsatisfactory situation of the shipbuilding industry of the United States, a situation which is of course incident to and a result of the unsatisfactory situation of our merchant marine.

Fortunately during the past year there have been some naval contracts and there is a good prospect for more, but as regards new merchant work it is still a case of hope deferred.

Without burdening you with statistics the merchant marine situation may be pictured in a few words.

STATUS OF THE U. S. MERCHANT MARINE

While as to total tonnage we are second only to Great Britain, in one respect we are first and the rest of the nations including Great Britain are nowhere. We are preeminent and lead the world in idle, unused, laid-up and out-of-date tonnage.

When we consider building it is another story. At the beginning of October we were seventh in tonnage building. The six countries ahead of us in the order of amounts of tonnage building were Great Britain, Germany, Italy, Holland, France and Denmark. Sweden and Russia were each only about 10 percent behind us.

Looking at the matter in another way, of completed world tonnage, if we include our idle and unused tonnage, the United States owns something like 20 percent—not an unsuitable figure considering the magnitude of our commerce. But of the new tonnage being built in October the world over only 3 percent was under construction in the United States.

PACIFIC YARDS DEAD

The story of this percentage is fully confirmed by the concrete situation of our shipyards. On the Pacific Coast before the World War there were building yards on Puget Sound, San Francisco Bay and in Southern California. Today on the Pacific Coast not only have the mushroom wartime plants vanished, but the pre-war yards with minor exceptions are as regards building closed or in a state of suspended animation.

ATLANTIC YARDS DYING

On the Atlantic the yards as a whole are going steadily down hill though they are not quite so near the bottom of the hill as on the Pacific.

The year just past has seen the final chapter of dismantling of the yard in Maine that for more than twenty years led in designing and building our naval destroyers. Nowhere were better destroyers built than at Bath.

Upon the Delaware a yard where ships had been built for 97 years completed three passenger vessels unsurpassed in their class in design, material and workmanship, and closed its doors.

Only upon the Great Lakes and our inland waters have the building yards held their own during the past year.

OVERSEAS COMMERCE UNDER THE AMERICAN FLAG

As regards overseas commerce, the figure of 51 percent fixed in the congressional declaration of policy of 1920 as the least proportion that should be carried under the American flag has never been reached, and we are now handling about 30 percent of our overseas commerce under our own flag. However, this percentage taken alone is liable to give a wrong idea of the condition of our overseas carrying trade. It includes for instance the operations of tankers owned and operated by oil companies as an incident of their major business.

If we consider the carrying trade proper, excluding vessels owned and operated by large companies mainly in connection with their own products, the American flag percentage would be well below 30.

MULTIPLICITY OF REMEDIES HINDERS IMPROVEMENT

Perhaps you think I have now reached a point where there should be given a formula or prescription that would remedy the situation. That would be easy but I am not going to do it. One great reason why matters have reached their present pass is that there are so many methods of remedying them—all perfectly sound as a remedy.

Considering three broad divisions only (each has in it any number of possible variations) it is obviously possible, mechanically under suitable financial arrangements, that this country could have a merchant marine doing 51 percent of its carrying trade under Government ownership and operation, under Government ownership and private operation, or under private ownership and operation.

The trouble is that hardly any two of the very large number of doctors that have been and will be consulted agree fully as to the relative cost and desirability of the many possible prescriptions that will cure the patient who for lack of *some* prescription grows steadily worse.

Of course there are doctors that do not think that the patient should be cured. There are plenty of foreign doctors who are prescribing in the case though not ostentatiously.

The foreign doctors and some few of our own claim that the world, including the United States, would be happier and better off if we abandoned the idea of an overseas merchant marine and let the patient die; that we could rely upon foreign flag ships to do our carrying trade better and more cheaply than we can do it under the American flag.

Without venturing into the fields of diplomacy and international relations it is to be hoped that happenings in those fields during the past year have brought home to our people the fact that every nation considers its own interests first, last and all the time. Once wholly dependent upon foreign flags for our carrying trade the inevitable corollary is that we would pay through the nose.

OUR CITIZENS WANT AN AMERICAN MERCHANT MARINE

The nation-wide investigations completed by the Shipping Board last winter made it quite plain that a vast majority of our citizens wish a merchant marine under the United States flag.

Let us hope that the coming session of Congress—a very critical one for the merchant marine—may produce a plan that will at least start our shipping on the road to health.

RELATIVE HIGH AMERICAN COSTS

Let me remind you at this point that of the complication of diseases with which the patient is afflicted the one which interests us most professionally is the excess cost of building ships in this country as compared with foreign costs. This is of course due mainly to the fact that wages enter so largely into the cost of shipbuilding and our wage scales are above those of other shipbuilding nations. Here again the doctors differ as to the amount of the excess cost. The exact amount, however, is not the thing of importance. With capital charges—interest, depreciation, insurance, etc.—25 to 30 percent of the cost of operation of a permanent merchant marine, we are under a crushing handicap whether our first costs are 40, 50 or 60 percent above the foreigner. I earnestly trust that when the merchant marine prescription is compounded it will take care of this question of excess first cost, directly and definitely.

With any roundabout scheme there will be less pressure upon the profession to reduce first cost and only by constant pressure in this direction and constant practice in building

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can we expect our excess cost to be lowered even if not wiped out.

Of course there are doctors who would give up our shipyards and have a foreign-built merchant marine under the United States flag. They would not kill the patient but only cut off a leg and an arm.

I hardly think the prescription, when and if it comes, will involve government expenditure to build merchant ships abroad or aid in the operation of foreign-built ships under the American flag.

TECHNICAL DEVELOPMENTS OF THE YEAR

Technical developments in our field during the past year as indicated by the papers read before the society have shown a progress that is steady but not startling. Pulverized coal has shown sufficient promise on tests ashore to warrant the Shipping Board giving it a service trial afloat.

Its advocates are confident that with its aid steam will make headway against the internal combustion engine. Meanwhile, the latter still makes progress and is being installed on more than half of the world tonnage now building.

As we devote the whole of our meeting to-morrow to pulverized coal and internal combustion papers, I will say no more on those subjects except to call attention to the remarkable advance during the year in the application of one type of internal combustion motor. I refer to the air-cooled airplane motor. This has been the development of several years but during the past year whether flying over the Atlantic and Pacific, carrying the mails in private hands, or in the Army and Navy, this type of motor has come into its own.

May I remind our engineers dealing with internal combustion engines for marine purposes that the air-cooled airplane motor of to-day weighs about 1½ pounds and costs about 20 dollars only per horsepower.

This weight and cost are recognized as too high and will probably be reduced next year.

IMPORTANCE OF RESEARCH WILL INCREASE

While our young members will see progress continue in the future, I think they will see it more closely associated than in the past with research—both as to fundamental principles and the myriad details whose sum is becoming more and more important as a factor in the product—the completed ship.

Trial and error were the main dependence of the generation now gone. They have served the present generation well in spite of the steady advance of science and research but for the next generation science and research should reduce trial and error to a minimum.

Existing model basins cannot deal satisfactorily with cavitation and for 30 odd years since Barnaby first identified and named the phenomenon of cavitation it has been a reproach to the science of naval architecture and marine engineering that no research has been made clearing up the many points still obscure in this connection.

One more illustration of a need for research and I am done. When we consider that the frictional resistance of nearly all types of ships is more than 50 percent and in some cases as great as 90 percent of the total it is evident that if this could be materially reduced every ship that floats would be better for it.

Of course a manufacturer of ship bottom coatings is usually prepared to demonstrate that his produce reduces friction. Such research as I know of in this connection indicates that the differences are infinitesimal but do we know that science has said its last word on this subject?

Here is a field for research that has been barren so far but some day may richly repay cultivation.

Car Float Strength and Deflection

By Prof. Evers Burtner and Richard H. Tingey

An abstract of this paper will be published in an early issue.

DISCUSSION

FRANCIS L. DU BOSQUE, superintendent, floating equipment, Pennsylvania Railroad, pointed out that in large organizations there is frequently a lack of cooperation between the different departments with the result that the department of greatest influence in the organization carries out its own ideas to the detriment of the others. In the railroad field this lack of cooperation resulted in the design of floating bridges which imposed extreme stresses on car floats. Up to 30 years ago all car floats were built of wood and the cars were much smaller than they are to-day. When the construction of steel car floats began, it was realized that the rule-of-thumb methods used in wood construction must be abandoned. At that time a large number of exhaustive tests were made by loading small steel car floats with cars of the largest capacity (80,000 pounds each). The floats were loaded and unloaded in various ways stressing them as severely as we dared. The cars were carefully weighed and we knew how much weight was imposed on the floats at the end of the bridge float. In this way it was possible to determine the stresses in the floats. The most important thing developed by these tests was the fact that it was found necessary to design the float bridges so that less load was imposed on the car floats. This led to automatically balancing bridge floats to reduce the live load on the car floats. Those experiments, which were made 25 years ago, showed the value of proper cooperation in all departments of the organization in assisting each other to attain a desired end. As the result it became possible to produce a car float that was cheaper and easier to handle and tow.

J. P. COMSTOCK: In launching small hulls, car floats, barges, dredge hulls, etc., difficulty is often found in reducing the area of ways sufficiently to obtain a satisfactory pressure on the grease without making the ways undesirably narrow. Launching on a center way, as described in this paper, provides a convenient means of doing this. In the cases of floats A and B, this method results in pressures of about 2 tons per square foot, at about which pressure most greases have the least coefficient of friction.. Even in these two cases we note that the starting rams were used.

Water ballast in the after tanks of car floats, usually built on ways whose under water length is excessive (being designed to launch larger hulls) the questions of moment against tipping and of way end pressure, which are often serious in launching large ships, are of no consequence. Accordingly, the tendency of stern ballast to aggravate both of these difficulties causes no trouble (although of course it should always be investigated) and the ballast has only beneficial effects. In this paper all of the plates show very little hogging over the way ends at the time of the least moment against tipping. The action of the starboard gage on float "x" is indeed peculiar. If it were due, as the writers suggest, to a horizontal bending, the port gage would be in error by a similar amount in the opposite direction. The set-up of the gage is in a measure checked by the fact that both gages come to the same reading after launching. One is forced to conclude that the action of the starboard gage throws some doubt on the reading of the port gage.

The delay in perceptible pivoting as contrasted with the advance in pivoting found with the *Malolo*, the *Yarmouth* and the *Evangeline*, as recently described in MARINE ENGINEERING AND SHIPPING AGE, may very well be caused, as the writers suggest, by the fact that at pivoting the deck at

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the stern was under water. Both the weight and the dynamic reaction of the water on deck would tend to hold the stern down and delay pivoting.

RIVET SLIPPAGE

The evidence of rivet slippage noted in plates 4 and 6 is surprising. It appears to be almost certain that in plate 4 the sheer strake butt near "x" slipped and threw a momentary concentration of stress into the deck stringer at "x," and in plate 6 the only gage that is placed across a butt shows, by an apparent stress twice that indicated by the surrounding gages, that that butt has slipped. And yet the relation between calculated and observed deflections would indicate that no slipping occurred. It certainly ought not to occur at the stresses indicated. One cannot help wishing that more gages had been placed across butts.

The load test of float "Y" is to this writer the most interesting part of the paper. The agreement between calculations and observations is comforting. It does seem somewhat arbitrary to include the rivet holes in the tension members, even though this does make the agreement still closer. But if it be assumed that the rivets clamp the parts so tightly that the heads and points are by friction made to experience the same tension that the other parts experience, there is some basis for the writer's position.

CONTINUITY OF LONGITUDINALS

One point in this connection should be emphasized. The longitudinals (we assume) are not continuous through the bulkheads, yet they are included in the cross section as though they were continuous. In spite of this, the calculated stresses and deflections agree with those observed. It might seem at first glance that this agreement justifies the assumption of continuity, but such is not the case. The situation is analgous to a notched beam. The deflection of a notched beam will differ only unappreciably from that of an unnotched beam, because the fiber-extension, for a given bending moment, will be just the same, except at the notch, as in the unnotched beam. Similarly, the stress, if measured by this same fiber-extension, will give no indication of the weakening caused by the notch. Only on placing a gage across the notch will evidence of the reduction of strength appear. It will be noted in plate 6 that in no case is a gage placed across a bulkhead, which would correspond to the notch in the beam. But if the beam be tested to destruction, obviously the notched section will determine the breaking strength. It is possible to use bulkhead connections which will develop the full strength of the longitudinal, without considering the deck or shell plating, and this may have been done in the design of float "Y." But unless it is done, it would seem axiomatic that in calculating the strength of the section (not the deflection of the hull) only that part of the strength of a longitudinal which is carried through the bulkheads should be used.

A FIELD FOR INVESTIGATION

Under "conclusions, load test, No. 3," the writers state that "the agreement of measured stress and deflection indicates that the modern car float design————is efficient." This agreement does indicate that the hull-girder acts as a whole,—that is, that the trusses are (at least) sufficient to tie the deck and bottom together and hold them to their work, and this is probably what the writers mean by "efficient." But it does not by any means indicate that the steel in the midship section is distributed to the best advantage. The wide variations both of arrangement and of scantlings of the midship sections of the standard car floats of the various railroads is evidence of the diversity of opinion on this point, and would appear to indicate a fruitful field for investigation.

The Design of Superstructures for Large Passenger Ships

By Carl E. Petersen and Lorentz Hansen

ABSTRACT

A thorough review of the transactions of the naval architects' societies both here and abroad, as well as of the technical press, discloses that the first really comprehensive discussion of this important subject took place in 1913, when Mr. J. Foster King presented a paper "On Large Deck Houses" before the Institution of Naval Architects. The pioneer effort of Mr. King was followed shortly by the monumental paper, "The Scantlings of Light Superstructures," by Dr. J. Montgomerie, which was read at the spring meeting of the Institution of Naval Architects in 1915.

Dr. Montgomerie states it is evident that, at present, no general principle guides the designer in his work, except that which finds its expression in an endeavor to save the greatest possible amount of material. The subject does not lend itself to mathematical treatment, and scantlings are found to vary widely among different builders to such an extent as to make the deduction of any common denominator almost impossible.

"In these circumstances it will be convenient to initiate the consideration of this subject by presenting two alternatives to the designer responsible for the structural design of long superstructures.

"1. The structure may be made so flexible that it cannot take any share in the straining action to which the vessel is exposed as a whole; or

"2. It may be made strong and rigid enough to share that general straining action without damage.

"A little consideration will show that the former of these two methods is impracticable. It is to be remembered that the deck house carries many heavy weights, such as boats, casings, and funnels, and that the structure must be sufficiently substantial to support these when the ship is moving in a seaway. It will be recognized that, if the superstructure is so flexible that it takes no share in the general straining action, it will certainly not be stiff enough to support the superimposed weights, and the only method by which both these ends may be attained is by cutting the structure at several places, and fitting expansion joints."

Dr. Montgomerie illustrates defects in the superstructures of vessels which have come under his observation and upon analysis, states that this supports certain conclusions which can be drawn from a consideration of the whole question of superstructures. These are as follows:

1. That in way of a discontinuity in the structure of a ship—for example, in way of a bridge or superstructure—stresses outside the erection will be transmitted to the material of the deeper girder in way of the erection much more rapidly than has been thought to be the case.

2. That, consequently, the fitting of expansion joints, spaced as in the present practice, does not appreciably relieve the superstructures of stress or obviate damage.

It may be observed that various explanations of this damage, more or less vague, are advanced from time to time. For example, the ship is spoken of as "shouldering her way through a sea"—a combined action of twisting and bending being implied—and it is a well known fact that the maximum stress resulting from such a combination is greater than that due to either of its components taken singly. But the straining actions to which a superstructure is exposed do not differ in their nature from those sustained by the ship itself. In the latter case, it has been the custom to divide the straining action into its component parts and to deal with each separately. There does not appear to be any reason why the satisfactory results obtained by this method in the case of ships' structures should not also be obtained when applied to the superstructures. It follows, therefore, that—

3. The best method of providing against damage in deck house superstructures is to adopt the latter of the two alternatives mentioned and to dispose the material so as to make these capable of taking part in the straining action of the hull, following as far as possible the general law that all discontinuity of longitudinal material should be minimized.

It has been the privilege of one of the authors of this

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paper to have been closely associated with large transatlantic passenger liners for a number of years, and he has as a consequence carefully observed the design and construction of these vessels; in short he has, what Sir Archibald Denny has referred to, had the opportunity to study what might be called the "morbid anatomy of ships." Perhaps the best illustration of defects in superstructures, resulting from superficially considered design, is that of a vessel coming under his observation.

This vessel, as originally designed and built, affords one of the best examples of that school of thought, more common two decades ago than at present, that the way to obviate defects in a long superstructure was to so design the superstructure that it would be so flexible that it cannot take any share in the straining action to which the vessel is subjected. The vessel was built by one of the foremost shipyards abroad in 1905 and before being interned here had been in the transatlantic passenger service. During, and for a period after, the World War, the vessel was engaged in transport service. The vessel has five full-length continuous decks and three superstructure decks. The shell plating extends up to the bridge (B) deck; above this the decks at sides are supported by angle stanchions or lattice work. A survey of the structural condition was made, and it was found that the structural defects on the vessel were confined to the erections above the strength (C) deck, with the exception of the fractures in the sheer strake doubling plates (21/20 inch thickness) next to C deck stringer angles at the four corners of the C deck main erection. No other defects in the main structure were found that would indicate in the slightest degree that the main hull of the vessel was not essentially sound and in good condition to meet any reasonable service demands. The principal scantlings of the hull appeared ample. Possibly the interior deck beam support in form of pillars and girders was not quite satisfactory. Examination of such support, however, revealed no deformation of these members or loose fastenings.

The fractures or defects found in the superstructure of this vessel may be attributed to one or more of the following causes:

1. Abrupt changes in strength of structure such as at the four corners of the C deck erection, and concentration of stresses at square corners of deck house window and door openings, etc.
2. Lightly constructed deck erections of too great a length without provision of adequate means for working of the structure when vessel is in a seaway. Expansion joints for this purpose are particularly necessary at not too great intervals where the lightly constructed erection plating is not in the same plane as the shell plating.
3. Inadequate support and improper distribution of topside weights by the decks under same, such as at the bridge front.
4. The arrangement of deck houses and other erections on the various decks, without regard to the relation of deck houses and erections above or below the deck under consideration and the tying-up of erections, otherwise islanded with steel girders.

The principal corrective features, which in the authors' opinion will fully eliminate defects in the superstructure and will prevent their recurrence, are:

(*a*) The redesign of the shell plating at the four corners of the C deck main erection and the provision of heavy horizontal brackets from B deck, connected to shell plating extending obliquely to C deck.

(*b*) The doubling of the B deck stringers and other strengthening measures to make this deck contribute greater strength to the structure.

(*c*) The support provided at the forward end of the B deck house in the form of heavy webs to take the A deck overhang above, the barriers and fashion plates to take the deck over.

(*d*) The redesign of deck house plating in way of door openings; these to have well-rounded corners and the section area of plating maintained by adequate doublers, above and below the opening with efficient riveting. The renewal of all damaged deck house plating of heavier material, and eliminating all square corners at window openings.

(*e*) The fitting of three expansion joints in the vessel's superstructure above B deck. (In this vessel actually but two expansion joints were fitted.)

It is obviously impracticable in this vessel to make the superstructure so strong and rigid that it will share in the straining action to which the vessel is exposed as a whole, without damage; therefore strengthening the first superimposed deck and cutting the superstructure above for relief was resorted to.

Particular attention is invited to the means adopted to take care of the concentration of stresses just below an expansion joint. The deck in way of the deck house, as well as the deck house coaming, have been doubled and special care taken to obtain efficient riveting, it having been observed in several vessels coming under observation that trouble develops in this locality.

Another matter about which some difference of opinion exists is whether it is the "pull" stresses due to hogging or the "push" stresses due to sagging that cause the severest damage to the superstructure. The late Dr. Thearle believed that the trouble is more due to the "push" stresses than from the "pull" stresses; also that the tendency of superimposing erection upon erection is calculated to give more trouble on account of the pitching stresses that are set up than by reason of the hogging or sagging stresses communicated to the superstructure by the vessel itself. Observation of defects in superstructures inclines one to the view that stresses due to pitching of the vessel and the "push" stresses due to sagging are the more severe.

It should be noted that, when additional material is worked into a lightly constructed erection above the strength deck of a vessel, increase in strength is not necessarily obtained, as the increase of the moment of inertia, I, may be offset by the increase of y, so that even greater stresses result. When a lightly constructed superstructure is added to the hull of a vessel the position of the neutral axis is not greatly affected, but y is naturally greatly increased.

Where expansion joints are not fitted in the superstructure, the erection (decks and houses) should have such effective longitudinal scantlings as will give a value $\frac{I}{y}$ equal to that of the main structure. Particular attention should be given to insuring continuity of deck house material, and adequate compensation provided at all openings. Corners of all door and window openings are to be well rounded. Where openings are compensated for, care should be taken to obtain efficient riveting as well.

In connection with the transverse support commonly found in vessels where defects have developed in the superstructures it is interesting to quote what the late Mr. L. Peskett stated in the paper he presented before the Institution of Naval Architects in 1914. This is as follows:

"It has become the practice of the Cunard Company within recent years to devote great care to these preliminary structural designs. The transverse watertight bulkheads are continued as diaphragms throughout the entire structure from keel to boat deck, being made to fulfil various functions in several parts of the ship. Up to the under side of the bulkhead their function is to provide watertight subdivision, and, of course, transverse strength; above this deck the strength is continued by webs and buttresses, but a light bulkhead is preserved, and plays the part of a fire-screen, being fitted with fireproof doors. Finally, in the form of webs and buttresses, these diaphragms are made to support and stiffen the superstructure and upper works. To this continuity of transverse members they have come to attach great importance, and the whole subject of the design of framework of the ship is made to take precedence, if necessary, of the minor conveniences of general arrangements. It has been in cases where discontinuity was the salient feature that the company have experienced the greatest expense in structural upkeep."

Having proper and adequate transverse support in the form of bulkheads, webs, buttresses, etc., for the superstructure is considered of such importance that an analysis

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and calculation of the transverse forces acting upon the superstructure of a vessel are given.

Having arrived at the scantlings of plating and local stiffening of the superstructure decks and house sides, the problem then remaining is to find the dimensions and spacing of the transverse stiffening members. These members should be sufficiently strong to take up all transverse or racking forces coming upon the superstructure and transfer these forces to the strength deck of the vessel.

The transverse forces acting on a large superstructure when a vessel is rolling in a seaway are:

1. The static forces due to the weight of the superstructure acting through its center of gravity when the vessel is at angle to the vertical.
2. The dynamic forces set up when the vessel is rolling among waves.
3. The wind pressure forces. These are not usually taken account of in ship calculations. Although these forces are of minor importance in the average case, they become marked when a large superstructure is exposed to a side wind of such an intensity as to cause a pressure of 10 pounds per square foot, say, corresponding to a 50-mile-per-hour wind, a fair average of what vessels have to contend with during the winter months on the North Atlantic service.

In considering the wind pressure forces the total bending moment becomes

$$M_s + M_d + M_w$$

or, as seen from the foregoing

$$1{\cdot}5\ M_s$$

This expression can be used to calculate the scantlings and spacing of the transverse structural members of the superstructure. The arrangement and structural plans will determine the location of these members. In determining the weight of the superstructure, account must be taken of the weights of the passenger accommodations, boats, equipment, etc., which from several calculations made of transatlantic liners has been found to approximate 85 percent of the superstructure steel weight.

Special consideration should be given to the sections in way of the boiler and engine casings with heavy casing bulkheads, and stacks supported by the superstructure.

It should be observed that the equation is in the most simple form so that the calculations necessary for the determination of the transverse structural members of the superstructure may be easily and readily made, having at hand the amidship section of the vessel showing the scantlings.

Observation and study forces the opinion that adequate and efficient transverse support is of prime importance owing to its bearing upon longitudinal strength. For this reason particular attention was given to this feature.

DISCUSSION

HUGO P. FREAR: The example illustrated on Plates 1 and 2 is so exceptional and remarkable that it is unfortunate more was not said regarding the scantlings, local design and workmanship in way of some of the more serious cracks. Occasionally cracks seem to be erratic and difficult to fully understand, but generally a satisfactory analysis can ultimately be arrived at. Sometimes cracks develop only at one place, on one, or both, sides of a house where no amount of patching or reinforcing prevents their recurrence.

The tendency appears to be to depend more on substantial erections and less on expansion joints than formerly. The circumstances of a particular case must be carefully considered before deciding whether or not expansion joints are either necessary or desirable.

In the third paragraph on page 6 Mr. Petersen has pointed out that both the I and Y values will be increased by including a part of the superstructure in the calculation and yet the modulus of $\frac{I}{Y}$ may be decreased, with the result that the stresses will be higher. This will occur when the part of the superstructure included in the calculation is too light to secure the same modulus as where the superstructure is not included. As the I is increased by adding more material to the superstructure the neutral axis is raised and Y increased so that the desired $\frac{I}{Y}$ or modulus and stress can be obtained.

This feature was given careful consideration by the Bureau of Construction and Repair in designing the 7,200-ton scout cruisers. Rumors were afloat that these cruisers were deficient in strength. Investigators in checking this up found that the vessels were not only amply strong but that the $\frac{I}{Y}$ and stress were almost identical both with and without the superstructure included.

W. BENNETT, Lloyd's Register of Shipping: The subject seems to fall naturally into two divisions; (a) the provision of adequate strength and stiffness in the material of the superstructure, and (b) care of the local arrangements in way of all openings in same.

It cannot but be admitted that the experience gained during the past decade has fully borne out the conclusions stated by Dr. Montgomerie in his able paper on this subject read before the Institute of Naval Architects in 1915, namely that superstructures cannot as a practical proposition be constructed so flexible as not to share in the vessel's straining action, but that the material should be so disposed as to render it capable of withstanding the effect of such action. The recommendations now made in the Rules of Lloyd's Register of Shipping covering this aspect are brief and concise, but, I submit, adequately cover the subject in all essentials. In short, these rules require that the sides and ends of large deck houses are to be supported by partial bulkheads and web frames, together with intermediate vertical stiffeners. It is recommended that the spacing of the partial bulkheads, or webs, is not to exceed 30 feet, and where possible these are to be fitted above the structural bulkheads of the vessel. Web frames should also be fitted where possible, at the sides of large doors. Care is to be taken, as far as possible, to minimize the effects of all discontinuities in the structure of deck houses, and it is recommended that continuous coamings should be fitted below and above doors and other openings, and that the corners of all openings cut in the sides of deck houses should be well rounded.

The question of stress concentration at corners of deck house openings is one which is given less consideration than the subject warrants. Just as failures in tail shafts frequently commence at the root of a keyway where there is a very high concentration of torsional stress, so a small circular hole in a plate subjected to tension results in a severe stress concentration at the sides of the hole which amounts to about three times the normal stress value.

The importance of well rounded corners together with efficient and adequate doublers can easily therefore be recognized. There seems to be a general opinion that fractures in superstructures in way of points of highly intensified stress are due more to sagging than to hogging stresses. On the other hand, it seems to me more likely to be due to failure under repeated stress, or in other words what may be termed "progressive failure." It is quite reasonable, I think, to conclude that at the corners of most openings in superstructures there may be found a combination of high stress concentration due to the discontinuity of the strength member, and cycles of repeated stress which may be above the endurance limit. It has been shown that for ordinary mild steel the endurance

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limit under repeated stress is about half the ultimate tensile strength, but if the elastic limit is less than the endurance limit, the lower amount is the criterion to be considered.

I feel sure the members generally will not, for reasons similar to those stated above, disagree with the author's proposal to limit the use of expansion joints (in the case of the vessel described in the paper) to above the promenade deck, especially when one considers that the formulae used in computing the stresses are based on homogeneous materials with no sudden discontinuity in the strength members, neither of which are ever more than approached in practice.

The "Wampanoag"—The Fastest Ship in the World—1868

By James Swan

ABSTRACT

Very shortly after the commencement of the Civil War it became evident that the most vulnerable point for attack on the northern states lay in their enormous merchant marine, engaged in foreign trade. The Confederates were not slow in taking advantage of the opportunity offered to do incalculable damage to their adversaries. A number of cruisers, notably the *Florida* and the *Alabama*, were equipped and sent to sea with all the expedition possible, and by 1863 the havoc wrought by these vessels had reached such proportions that the whole north was clamoring for immediate measures by the national government to accomplish their destruction and insure the Stars and Stripes upon the seas, from which it was rapidly being driven. A deeper and even more compelling reason for unusual efforts in the increase of the northern naval forces lay in the threat of foreign intervention in the war between the states, a threat which in 1863 was a very real one and the cause of the gravest concern to the government at Washington.

The answer to the call for protection on the high seas and the possibility of embarking in a great naval war came in the laying down, at the Boston, New York and Philadelphia navy yards, of a class of six large cruisers, of greater length and designed for a far higher speed than anything which had preceded them in this country or abroad. These ships were the *Ammonoosuc* and *Pomponoosuc*, which were laid down at Boston, the *Wampanoag* and *Madawaska* at New York, and the *Neshaminy* and *Chattanooga* at Philadelphia. The *Chattanooga* was built at Cramp's shipyard.

The design and construction of these vessels presented problems with which the shipbuilders and engineers of this country had never before been confronted. The power required, per ton of displacement, was far greater than anything previously attempted in seagoing vessels, and the resulting great and concentrated weights to be carried by it made the design and construction of the hull a matter of supreme importance, one for which no precedents existed.

With a view to taking advantage of all available skill in the design of the new ships, the Secretary of the Navy called into consultation Mr. Benjamin F. Isherwood, at the time chief engineer of the Navy and in charge of the Bureau of Steam Engineering. Mr. Isherwood was a man of unusual attainments in the scientific side of his profession. His first recommendation was that the new vessels should be built of iron as he doubted the possibility of constructing wooden hulls which would successfully withstand the concentration of weights and the vibrations resulting from the enormous and high-powered machinery which would be required. This proposal, which scientifically was quite sound, was emphatically negatived because of the practical limitations which then existed in the navy yards. Even in Great Britain iron shipbuilding was in its infancy, while in this country practically no facilities for the construction of large iron vessels existed, and there was no time to get them.

Wood being decided upon, Isherwood advised such a distribution of displacement, in designing the hulls, as would ensure the greatest possible amount of buoyancy support in way of the machinery. In the general layout of the ships this idea was evidently kept in mind as the engines were placed nearly amidships and the boiler weight distributed, approximately symmetrically, forward and aft of the engines. Apparently it was not appreciated by the constructors that Isherwood's advice applied to the lines as well as to the general arrangement of the vessels, for when he was shown the midship frame of the first ship set up in the ship house at New York, he asked to be relieved of any responsibility for the vessel's design as, in his opinion, she was foredoomed to be a failure. Apparently the whole responsibility was then "put up" to him. A new model was got out at the Navy Department by Mr. Richard Powell, under Isherwood's supervision and in accordance with his ideas. The lines of this model were taken off, faired and perfected by Mr. Benj. F. Delano, naval constructor at the New York yard. So far as the writer has been able to ascertain, the only lines now in existence, of all the six vessels, are those of the *Ammonoosuc*. These were found stored away at the Washington Navy Yard. A half model of the same vessel is preserved at the Boston yard, where she was built. Although slight differences in dimensions existed, there can be little doubt but that all six ships were laid down from the original model made in Washington by Mr. Powell. The recorded lengths and breadths of the six vessels were as follows:

Ammonoosuc	335 feet by 44 feet 4 inches
Neshaminy	335 feet by 44 feet 4 inches
Wampanoag	335 feet by 45 feet 2 inches
Madawaska	335 feet by 45 feet 2 inches
Pomponoosuc	335 feet by 48 feet
Chattanooga	315 feet by 46 feet

The *Ammonoosuc's* lines were quite different from anything which had preceded them in naval work. Instead of the almost barrel-shaped midship section of the old frigates, a squared section was adopted, approaching the approved practice of today. The ends were fined down, the forward water lines showing a decided hollow, the general effect being quite similar to a modern destroyer. By this means the displacement amidships, under the machinery, was increased, and at the same time very nearly ideal lines for speed resulted. To further help the weight distribution, the old overhanging bow was dispensed with and a plumb stem fitted, and in the way of the engines the frames were diagonally strapped with bar iron over which the planking was run. The success of the structural side of the design is demonstrated by the report that these were the first large wooden steamers which kept their shape and neither sagged nor hogged.

So much for the hull. The machinery presented equal novelty and difficulty to the engineers. Mr. Isherwood felt that with direct-connected, fast-running engines the resulting combination of weight and vibration would be more than a wooden hull could withstand and proceeded to design geared engines in which the crank shaft revolved at approximately half the rate of the propeller. This type of machinery was fitted in the *Wampanoag* and *Ammonoosuc*, the only ships of the class which came up to expectations as regard speed. Direct-connected engines were installed in the *Madawaska* and *Chattanooga*, the only

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others of the class to be completed, but neither of these approached the speed attained by the geared ships.

The engines of the *Wampanoag* and *Ammonoosuc* even today appear enormous, the space taken up by them on the ship being 26 feet athwartship and 46 feet fore and aft. The entire length of vessel occupied by engines and boilers was 166 feet 7 inches.

The following dimensions are of interest:

Diameter of cylinders (2)	100 inches
Stroke	48 inches
Piston rods (2 to each cylinder)	7½ inches
Connecting rods	10 feet centers, 12 inches maximum diameter
Crank pins	16 inches diameter by 27 inches
Crank shaft journals	18 inches diameter
Crank shaft in way of gear	21 inches diameter
Pitch diameter of main gear	10 feet 3 5/16 inches—wooden teeth
Pitch diameter of pinion	5 feet 9/16 inches—iron teeth

Perhaps the most interesting single feature of these great engines was the enormous gears, designed for a purpose just the opposite of that of their present-day counterparts. The large drum had 84 teeth, and the smaller gear, on the propeller shaft, 41, the revolutions of the propeller thus being slightly over twice those of the engines. There were nine sets of teeth each 12 inches wide, those on the drum being lignum vitae, keyed in place, and the gear having iron, machine cut teeth. The line shaft, fitted in four sections, was of forged iron 18 inches in diameter. The main thrust shaft had 18 collars, 23 inches outside diameter, and in addition an adjustable roller thrust bearing was installed, so arranged that either bearing could be made to take all or part of the thrust. Evidently the old saying that "There is nothing new under the sun" applies in marine engineering as elsewhere. Forward of the thrusts a disengaging coupling was fitted to allow the propeller to revolve freely when the ship was under sail.

The propeller was a solid, four-bladed wheel of bronze (88-10-2), 18 feet in diameter and having a pitch expanding axially from 23 feet 6 inches at the leading edge to 26 feet 6 inches at the trailing edge of the blades. The latter were 9½ inches thick at the hub and ¾ inch at the tips.

As was the rule in steam vessels of the Civil War period, there was very little independent machinery. Electric lighting and power were, of course, undreamed of, and the entire list was comprised of four flywheel donkey steam pumps each of a capacity of 500 gallons per minute against boiler pressure and a fresh water distiller having a capacity of 2,000 gallons in twenty-four hours.

Steam was supplied by eight Martin boilers, a type extensively used at the time in American naval vessels. These boilers were a combination of the old tank boiler with the watertube principle, the horizontal firetubes of the older type being replaced by vertical watertubes. The four boilers nearest amidships and the two forward ones had seven furnaces each, while the two after ones had six. The vertical watertubes were of brass, 2 inches in diameter, the total number in all eight boilers being 16,082. The bottom shell and lower side plates of the boilers were 7/16 inch in thickness, ash pits 7/16, furnaces and bottom of smoke connection 3/8, and tube sheets ½ inch.

In addition to the eight main boilers, four superheating boilers were installed, forward and aft of the engines. These had horizontal tubes, 2 inches in diameter, and were connected to the main boilers.

The total grate surface of all boilers was 1,128 square feet, the water heating surface 28,000 square feet, and the superheating surface 2,848 square feet. The designed maximum working pressure was 40 pounds per square inch. There were four smokestacks, extending 56 feet above the uptakes and having a total height above the hull base line of approximately 80 feet. The two middle funnels were 7 feet 8 inches in internal diameter, the forward one 6 feet 6 inches and the after one 6 feet 3 inches. Steam jets were installed in the stacks for induced draft and an 8-inch lever safety valve fitted to each boiler. The main steam pipes were of copper 21½ inches in diameter.

The total gross weights of the propelling machinery were given by Mr. Isherwood as follows:

	Pounds
Boilers and mountings, floor plates and piping in boiler rooms	1,051,000
Engines, including clutch coupling, floor plates, etc., in engine room	1,171,700
Shafting, bearings and propeller	150,700
Water in condenser, paint, putty, felt, lead, lagging, etc.	58,500
Water in boilers	385,000
Auxiliary pumps and connections	21,500
Total gross weight or 1,267.5 tons	2,838,400

The net weight of the machinery as checked from the actual drafts of the ships when afloat by Naval Constructor Delano was 1,250 tons.

As was the then universal practice, the *Wampanoag* and her sister ships were given a good spread of canvas and they were fairly handy vessels under sail, notwithstanding their great length. The sail plan of the *Ammonoosuc* shows a total area, for head sails, courses, topsails, topgallant sails and spanker, of slightly less than 20,000 square feet. The ships were originally designed with no bowsprits in order to make the plumb stems immediately available for ramming. The bowsprits and additional head sail area were later added to give a better balanced sail plan.

The armament, for ships of such large size, was small, everything being subordinated to the main and essential requirements of maximum possible speed. It consisted of one 60-pounder pivot gun on the forecastle, two 60-pounders on broadside mounts, ten 9-inch guns in broadside, two 24-pound howitzers, one 12-pound howitzer and one 12-pound rifled howitzer.

The great cruisers were designed and work on them started in 1863. The hulls were rapidly pushed forward towards completion, but the machinery presented greater difficulties, so that when the Civil War ended in 1865, none of the ships was completed. The first to be finished, the *Madawaska,* came out in 1866 and went on trial in January, 1867. Her performance seemed to bear out the storm of criticism which had been directed against the vessels by certain naval officers and service journals since their inception. Designed for a minimum speed of 15 knots, the *Madawaska* on a forty-one hour sea trial made an average speed of only 12.73 knots and this with a heavy expenditure of fuel—over 5 pounds of coal per horsepower hour. This ship was fitted with Ericsson "vibrating lever" engines, directly connected to the propeller shaft. Her boilers were duplicates of those on the *Wampanoag.*

The *Wampanoag* was the first of the geared engine vessels to be tried. These ships had been the subject of particularly harsh criticism apparently mainly directed at Mr. Isherwood himself, as the designer of their machinery. Just two weeks before the trial the following appeared in a leading service journal: "We are free to say that there is no such monument to mechanical incapacity as the steam machinery of the *Wampanoag* class to be found in the annals of marine engineering," and much more to the same effect.

On February 11 the full-power trial was commenced at 9 P. M., the ship then being 20 miles north by east of Barnegat Light. For thirty-eight hours she was driven south some 20 miles off the coast. Everything worked

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perfectly, the speed being limited only by the rate at which coal could be fed to the furnaces by an undrilled and eventually worn-out fireroom crew. As the vessel proceeded south the wind steadily increased until she was running through a rough sea, rolling heavily but still logging in the neighborhood of 17 knots. Confronted by the prospect of yet worse weather, the trial was concluded about 30 miles southeast of Tybee Light, at the mouth of the Savannah River. In a few minutes less than thirty-eight hours elapsed time, the *Wampanoag* had steamed over 630 nautical miles, an average speed of 16.758 knots per hour, and had proved herself to be, without question, the fastest ship afloat.

The following are some of the figures turned in by the trial board:

Mean draft of water	18 feet 6 inches
Displacement	4,215.54 tons
Block coefficient	0.566
State of sea	Rough
Wind	Strong Breeze
Coal consumed per hour-total	12,670 pounds
Coal consumed per hour, per sq. ft. of grate area	11.23 pounds
Temperature of feed water	138 degrees F
Mean revolutions of engine, per minute	31.265
Mean revolutions of propeller, per minute	64
Mean steam pressure, lbs. per sq. in.	32.43
Vacuum in condenser	24 inches
Mean indicated horsepower	4,048.8
Coal per I.H.P. per hour	3.129 pounds
Mean speed of ship, knots	16.758

The *Wampanoag's* performance was in the nature of a tremendous personal and professional triumph for Mr. Isherwood and a staggering and unwelcome surprise to his opponents. He is said, however, to have manifested little elation at the results, apparently having had entire confidence in the soundness of his work.

After the critics had had time to recover from the shock, the work of belittling the ship's performance and abusing her designer was again taken up, both in this country and abroad. The speed reported was stated to be impossible of attainment, the machinery far too heavy for the power developed, and the ship, as a whole, characterized as a freak and utterly useless.

Additional evidence of the phenomenal speed of the new vessel was, however, not long in being produced. On June 15 and 16, 1868, the *Ammonoosuc* was tried and made a speed of 17.11 knots over a 50-mile course, the propeller revolutions being 67 per minute.

This, in outline, is the history of the active career of these two remarkable vessels. Neither of them saw any actual service. The war was over when their trials took place, they were anything but peace-time ships, and shortly after their initial runs they were placed out of commission and laid up. The remainder of the story is soon told. In 1869 a board of naval officers was called to examine and report on steam machinery afloat at the various navy yards. This board condemned the *Wampanoag* for many and various reasons, among them the following: "Excessive weight of machinery and coal, enormous coal consumption, because the grate surface was 1.53 times the midship section area, carried coal for only five or six days steaming at maximum power, because the four-bladed screw interfered with the use of canvas." In the light of later developments of marine engineering the report is a curiosity. At least it clearly reveals the working of "the intelligent naval minds" of the day, for in such terms the board modestly refers to itself.

Renamed *Florida,* the *Wampanoag* served as a store ship at the New London naval station for a number of years, and finally, in 1885, was sold and broken up. The *Ammonoosuc,* under the name *Iowa,* was laid up at the Boston yard for many years and eventually broken up in 1883.

So much is history. There can be no doubt but that the two vessels described were the fastest of their time and that their performance, as contrasted with that of their less successful sisters, fully vindicated Mr. Isherwood's judgment in fitting them with the heavy geared machinery. While they saw no actual service, they accomplished their purpose in forming a most formidable addition to the country's naval forces when, after the close of the Civil War, potential naval power was a most important and vital background to the foreign negotiations and adjustments then under way.

The Submarine of Today

By Lawrence Y. Spear

An abstract of this paper will be published in an early issue.

DISCUSSION

MASON S. CHACE declared that in this country we have been wasting time building small boats. If we want to build a real submarine we must increase the displacement from 3,000 to 9,000 or 10,000 tons and supply machinery to give a speed of from 18 to 21 knots. He believed that it is entirely possible to build a submarine of 20,000 tons displacement.

CAPTAIN J. H. LINNARD, U. S. N., Retired, stated that the data in the paper showed the relatively small value of increased displacement and pointed out the possibility of crash dives in large vessels.

COMMANDER HAROLD E. SAUNDERS, C.C., U.S.N.: One very commendable feature pertaining to submarine design which I believe is published here for the first time is the statement of percentage of reserve buoyancy in the full load condition with maximum fuel oil. Although perhaps not generally understood by the naval architects who design other types of ships, it is the percentage assigned to this reserve of buoyancy with the maximum load of fuel oil on board which really determines the capacity of ballast tanks, the freeboard and certain other features which have to do with the behavior of the vessel in the surface condition.

With particular reference to the data set forth on Table 7, page 10, concerning mine laying submarines, I think it should be pointed out that the number of mines carried by the German *U-117* class is not exactly comparable to the number of mines carried by the other vessels mentioned. The *U-117* and her sister ships could carry 34 mines in the stowage racks, 2 on the elevator platforms and 3 in each of the two mine tubes, making 42 in all. However, the published records indicate that on some of the vessels of this class the number of mines in the racks had to be reduced to as low as 28, on account of overweight, and such data as are at hand lead one to believe that mine tubes were not ordinarily used for the stowage of mines. I feel, therefore, that the number of mines carried by the German *U-117* class should be set down as 32 to 36 rather than 42 to 48.

It is of interest to note that on November 10 we are launching the submarine *V-4* at the Navy Yard, Portsmouth, N. H., the largest submarine so far constructed by any Navy.

Model Tests with Adjustable Blade Propeller

By Captain William McEntee, C.C., U.S.N.

This paper will be published in an early issue.

DISCUSSION

REAR ADMIRAL C. W. DYSON, U. S. N., retired, was of the opinion that the conclusions are too definite for the

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ground covered and took exception to the change of pitch up.

W. W. SMITH, chief engineer, Federal Shipbuilding Company: On pages 1 and 2 it is stated that ⅔ radius was used for setting the pitch so as to approximate the performance of a constant pitch screw. Our practice is to use a radius of 0.7 for this purpose.

Referring to Fig. 3, if 0.7 radius had been used, the effective pitch ratios of propellers 595 and 596 would have been greater. Also, the thrust coefficients, torque coefficients and efficiencies of these propellers would have been higher. In Fig. 1, the results for propellers 594 and 595 would have been the reverse. In Fig. 2, the values would have been greater for 596 and less for 594. In other words, the curves would have been brought together into closer agreement.

If the effective pitch ratios are the same for all wheels, it appears that, allowing for inaccuracies of tests, the thrust coefficients, the torque coefficients, and the efficiencies will be the same, or sufficiently so for practical purposes. It would have been preferable, it seems, to have adjusted the blades until the curves of thrust coefficient coincided, and then to have determined the radius at which the pitch was the same as that of the constant pitch screw.

The radius which would give these results can be computed, but it appears that 0.7 radius would bring the curves into closer agreement, and that the use of this value is preferable to ⅔ radius as given in the paper.

The changes in pitch used in these tests vary from 20 to 67 percent of the designed pitch and are much larger than used in practice, where a maximum of about 10 percent is usually allowed. Thus, the test values are from 2 to 7 times the values used in practice. With the small changes used in practice the values will be in much closer agreement than indicated by the curves.

Referring to conclusion 1 on page 2, the differences in practice will be so slight that it appears desirable to design the propeller as usual with a constant pitch as determined by estimate or test.

The curves are carried to a nominal slip ratio of about 35 percent. Propellers are frequently run at considerably higher slip ratios, and it would be desirable to have the curves extend to higher values—say 60 percent or more. For example, the ρ value for our Hull 84 was 28.4, and for our Hull 83, it was 33.2 as compared with a maximum value of 22 as given in Plate 4. I think that the practice of the Washington tank should be modified in this respect so as to cover fully the range used in practice.

In this connection, I should think it would be better to use constant revolutions, and vary the speed of advance. If this were done, there would be no difficulty in carrying the curves to 100 percent slip as was done by Dr. Schaffran.

On page 1, the author notes that the efficiency runs about 2 points higher than the values given in Admiral Taylor's article. This may be due to the larger hub, or rather to the shorter blades, since the resistance of the hub was deducted. Including the latter, however, the propulsive efficiency with a larger hub would probably be less for the same diameter, and about equal for the same net area, or sectional area of the stream acted upon by the blades.

E. A. STEVENS, JR., found it hard to explain why there was so much change in the propulsive efficiency in Plate 3 and so little in Plate 2. The efficiencies here are not propulsive efficiencies, he said, but propeller efficiencies and do not take into consideration the effect of the hull on the wheel. If these wheels had been tested behind a model the data would have been more valuable.

COMMANDER J. M. IRISH, U.S.N.: In addition to the conclusions drawn by Captain McEntee as a result of his tests, it would appear that he has put a stop to those designers who have claimed such wonderful advantages from a blade with variable pitch. The tests show that it is possible to design a propeller of standard blade form with constant pitch which will give equal efficiencies with that of the variable pitch. From a point of view of costs of laying out and manufacture, the constant pitch blade is far superior, so that as a result of these tests no further doubts need exist as to the advisability of using it in preference to the variable pitch.

A case has recently come before the writer which confirms the tests in actual application. A propeller with projected area ratio of 0.30 and a pitch ratio of 1.072 was reset to a P/D of 1.024—a reduction of nearly 11 inches in pitch. The actual propulsive coefficient on trial over the measured mile changed from 0.682 to 0.652 on approximately the same relative loading of the propeller.

CAPTAIN E. S. LAND called attention to a very recent discovery showing that the pitch of blades of the Williams speed plane had changed in the speed trials due to crawling of the blade on the hub. He stated that in aviation there is great need of a variable pitch and reversing blade propeller.

PROFESSOR H. C. SADLER stated that in wind tunnel tests he tested the deflection of blades and found quite a considerable deflection.

Tank Steamer Fires and Explosions

By Robert L. Hague

An abstract of this paper will be published in an early issue.

DISCUSSION

A. C. HOLZAPFEL, president, International Compositions Company, New York: I believe that it is not the naval architect and engineer alone who are destined to contribute to the purpose which we all have in mind, i.e., of further safeguarding this industry. I believe the chemist and paint manufacturer are destined to play a not unimportant part in this matter. In the first place, I might call attention to the author's remarks near the bottom of the third page where he refers to explosions resulting from re-evaporation from rust and scale in tank ships. In the present state of evolution of the paint industry, I believe the formation of such rust and scale can be entirely avoided. Over two years ago, new synthetic gums have been evolved by the use of which the paint industry can produce paint materials, which in the first place are entirely insoluble in oil, gasoline and its vapors or condensations. Paints made from these materials have been under trial for nearly two years in various oil refineries and have proved their efficiency against three destructive agencies which have caused the formation of these heavy layers of rust and scale. These are: (1) The dissolving tendencies of light oils and their vapors, (2) the hydrogen sulphide gas which plays a very important part in this connection and (3) against sulphuric and hydro-chloric acids. In this connection I may perhaps be allowed to refer to hydrogen sulphide gas, the destructive effects of which perhaps are not fully realized by many naval architects and engineers. According to researches hydrogen sulphide gas has the capacity of directly combining with iron and steel and forming sulphide of iron. In connection with these researches it has been found that where hydrogen sulphide gas was present in very condensed form the formation of sulphide of iron was produced under conditions of temperature which in certain instances have resulted in explosions.

Naval architects and engineers have long been puzzled about the remarkable destruction of rivets and plates in tank ships as compared with other types of ships. Electrolysis produced by sulphide of iron resulting from the

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contact of hydrogen sulphide gas with steel surfaces has undoubtedly been the cause.

Half the explosions which have taken place on tank ships have probably occurred while these vessels were under repair. I venture to express the opinion that if and when these new paint materials to which I refer have been adopted by the oil trade and particularly if and when they are used in an intelligent and circumspect manner, most of these repairs will no longer be necessary. It must, however, be borne in mind that their first application will be a matter of delay and expense and that periodical renewals will be necessary although where they are covered by a film of crude or fuel oil they will, in my opinion, prove to be an effective protection for a decade or longer. In any case, I believe that by means of such a protection much more than half the cost and delay of repairs on tank vessels and the resulting danger of fire and explosion during such periods can be avoided.

ELMER A. SPERRY, Sperry Gyroscope Company, expressed his amazement at the danger of some of these operations and suggested that when samples were taken they should be taken in the corners of tanks as well as in the middle.

CAPTAIN DOWNS, Standard Oil Company, of New Jersey, stated that samples are taken in the furthest corners of all tanks and in all places where explosive gases may lurk.

What Is Naval Aviation Doing?

By Captain E. S. Land* (CC), U. S. N.

ABSTRACT

When commercial aviation was wallowing through the slough of despond naval aviation was carrying a very large share of the burden of keeping the best concerns going, by giving experimental orders, by aiding in experimental and technical development, and by such assistance, both technical and financial, as was warranted by the conditions existing at the time. It has been the policy to pave the way for extensive flights, particularly over the water, and in this way a great deal of exploration and pioneering work was done, some of the benefits of which are now being reaped by commercial aviation.

The policy of the administration is economy, and this is the foundation on which the present policies and the present activities of naval aviation are constructed. While naval aviation does not participate in special long-distance flights, it has given assistance to such flights in the way of technical advice, the use of special instruments, special charts, information relative to routes, weather, landing fields, supplies, etc., as well as the loan of expert personnel.

The very important and vital part played by naval aviation in the development of air-cooled engines is one of the greatest developments of which the Bureau of Aeronautics is particularly proud.

The development of equipment accessories, particularly engine accessories, has been one of the outstanding features in which naval aviation has been actively interested. The present hand starters in use might be cited as one of the most important improvements in connection with accessories that have been developed by the trade, with the technical advice and financial assistance of naval aviation. The development of the Oleo landing gear is another outstanding feature the development of which has been pushed as rapidly as practicable, and the results speak for themselves. The development of brakes is another important feature which is still under way. The development of a supercharger and its actual service use is another advance that will have far-reaching results in the tactics and strategy of aviation.

Naval aviation was the first to adopt the all-metal propeller as standard equipment throughout the service and concentrated efforts have been made with the trade to accomplish results along this line in the most expeditious and economic manner possible.

Marked progress has been made in the development program, making a transition from the so-called "wood and wire jobs" in aircraft to "all-metal jobs." In connection with all-metal work, the question of corrosion is one of the most serious problems with which naval aviation has to contend. By cooperating with the trade, particularly those interested in aluminum alloys and steel alloys, rapid advances have been made along lines which should produce much more satisfactory results than have heretofore obtained. This development of aluminum alloys, especially that known as "duralumin," was sponsored by the Navy and had an important bearing on the Navy's pioneer work in constructing large rigid airships.

A great deal of concentrated effort has been spent on the complicated subject of standardization. The closest cooperation with the Army Air Corps and the representatives from the trade has resulted in a great many modifications in our specifications which will standardize equipment, reduce cost, and improve results.

There is no feature in connection with design which offers improvement that has not met with a ready response on the part of those connected with this part of naval aviation.

A great deal of concentrated effort and study has been put on the question of safety. The gradual replacement of wood by metal in aircraft construction has been a material factor in reducing the hazard of flying. Considerable effort is being devoted to devices and designs to reduce landing speeds, and especially to improve control at speeds at or below the stalling speed. Such development is of particular importance in connection with landing airplanes on the aircraft carriers. The use of aircraft carriers has brought to the Navy a new problem; namely, the safety of personnel operating land planes over water. Flotation equipment, consisting in general of air bags, has been housed in various parts of the machine which may be almost instantly inflated from CO_2 bottles installed in the machine, by simply throwing a lever. Inflatable life jackets and the pneumatic life rafts are also a part of the equipment of these airplanes. The parachute is now well beyond the experimental state and has amply proved its value as a saver of life.

In addition to the specific items noted above, the development and improvement of all parts of the airplane are working toward safety. The increased reliability of power plants may be cited as probably the most important. The air-cooled engine with its low weight and absence of radiators and accompanying plumbing, a development in which the Navy has taken the lead, is among the most outstanding of these.

The increasing knowledge of the forces acting on aircraft has enabled the assignment of factors of safety which more nearly represent the true conditions than the former values.

During the past fiscal year, a procurement program was put through covering the purchases of 297 aircraft and 562 engines.

As a result of extensive flight competition tests, a training plane has been developed which is believed to be the equal of any training plane in the world and for naval training purposes is believed to be superior to any

*Assistant Chief of the Bureau of Aeronautics, Navy Department.

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other training plane in the world. These planes are now in use.

As a result of an experimental order, there has been designed, developed and constructed an observation plane which, as a flying machine, is the equal of any plane in the world and, so far as information is available, is superior. This is the O2U (Corsair) around the Wasp engine, which plane has already established four world's records and is an outstanding plane of its type. From all information available, it is believed to be superior to any other type of observation seaplane in existence.

As a result of extended flight competitions, two types of battleship fighting planes, the Curtiss F7C-1 and the Boeing F3B-1, have been developed which for installation on board ship are believed to be the equal of, if not superior to, any other planes of their type.

After repeated efforts on the part of the bureau, the Glenn L. Martin Company was persuaded to build, without any financial assistance on the part of the bureau, a three-purpose plane, V-STB, giving predominance in the design features to the bombing requirements of this type of plane. The ultimate result was the Design Model No. 74 (T4M-1) built around the Pratt and Whitney "Hornet" engine. The overall efficiency of this plane was so markedly superior to previous planes that the bureau purchased the plane from its experimental fund and, *after competition*, awarded a contract to the Martin Company for 54 of these planes.

The general public has been educated with regard to the advantages of the air-cooled engines and with the particular merits of the Wright "Whirlwind." A great deal less has been said about subsequent developments in air-cooled engines of greater horsepower and therefore of much more vital interest to naval aviation. Suffice to say that the Pratt & Whitney Company developed the "Wasp" engine, an air-cooled product of 400-425 horsepower. This engine is out of the experimental stage, is in production and in service. It speaks for itself. The Pratt & Whitney Company and the Wright Aeronautical Corporation have developed two larger engines of greater than 500-horsepower capacity, which are now practically out of the experimental stage, in the flight test stage, and in preliminary production. This air-cooled development, originally fostered primarily by naval aviation, has continued to be fostered by naval aviation, and the future looks particularly attractive with regard to these engines of comparatively high horsepower.

In connection with the procurement program previously referred to, it is a matter of considerable interest, not only to naval aviation but also to the trade in general, to realize that an orderly program of procurement has advanced so far in the present fiscal year that the trade is in a position to know just about what can be expected in the way of orders and therefore is in a position to order its material in a logical and economical way, the net result being that aircraft and aircraft engines for naval aviation are being procured in the most economical manner, again carrying out the major policy of the department.

Naval aviation can and does point with pride to the types of planes developed during the last fiscal year and now in production. Experimental units of each type are in service. This refers particularly to its training plane, to its two battleship fighters, to its observation plane, to its patrol plane and to its bombing plane.

If a national emergency were declared today, naval aviation would be in a position to place its orders immediately for the types best suited to the service. These types are already in production. Plans and specifications are ready and the trade is tooled up ready to produce on a moment's notice.

DISCUSSION

CAPTAIN H. C. RICHARDSON, C.C., U.S.N.: The engine mount of the racing plane is excellent, but differs slightly from what might be inferred from the description. The fuselage provides the usual four longerons, terminating at the engine bulkhead. On both sides of the engine crank case, two lug plates are bolted to the case. One lug comes at the c.g. of the engine and a rear lug near the rear of the engine. Each of these lugs is tied to the upper and lower longerons by diagonal tube braces, on each side, the upper tubes uniting in a single fitting, and the lower tubes doing the same. In this manner there is complete triangulation, and ample obliquity to care for lateral forces. The system is unusually neat and effective.

COMMANDER S. J. ZEIGLER, C.C., U.S.N.: Discussion of Captain Land's most interesting paper would not be complete without some mention of the present business aspect of naval aviation. The current supply bill for the naval establishment carries an appropriation for "Aviation, Navy" of $20,100,000. A contract authorization of $9,480,000 was also granted; this item contemplates negotiation of contracts, deliveries under which will be deferred into the future so long that the funds for payment may be appropriated in the next annual supply measure. The twenty million dollar appropriation and the nine and a half million authorization exclude sundry minor appropriations administered by the Bureau of Aeronautics, such as its allotment from "Increase of the Navy," "Pensacola Storm Damage," etc.

It is interesting to note, as evidence of Naval Aviation's having grown up to be one of the big sisters in the Navy's business family, that during the first quarter of the current fiscal year the value of aeronautical material inspected by the eleven inspectors of naval material exceeded that of material inspected for any other single Bureau of the Navy Department. Its value was $2,694,781. The comparison excludes all vessels, aircraft, etc., inspected by superintending constructors for the Bureau of Construction and Repair, inspectors of machinery for the Bureau of Engineering, and inspectors of naval aircraft for the Bureau of Aeronautics, and pertains only to purchases of general material inspected by the common inspection service.

The Bureau of Aeronautics got away to a flying start in the consummation of its procurement program for the current fiscal year, and considerably more than half of its appropriation and its contract authorization has already been obligated by contracts which have been consummated or which are in the final stages of negotiation.

Interesting items already contracted for or for which negotiations are now in progress include:

56 VF, battleship fighters, convertible land and sea planes.
41 VO two-seater convertible land and sea observation planes.
20 VO amphibian observation planes.
48 V-TBS, combined torpedo, bombing, and scouting, convertible land and sea planes.
25 VP patrol flying boats.
43 VN convertible land and sea training planes.
100 float type landing gears for training planes.
156 200 horsepower radial aircooled engines.
346 425 horsepower radial aircooled engines.
196 525 horsepower radial aircooled engines.

In addition, experimental contracts will procure:

1 XVF experimental all metal fighter.
1 XVT experimental torpedo seaplane, single engine, biplane, of novel float design.
1 XVP experimental patrol flying boat, three engined monoplane.
3 geared 200 horsepower radial aircooled engines.

Very fortunately it was possible, in the negotiations of contracts for the past fiscal year, to foresee the probable purchases of identical equipment from this year's funds, and 1927 contracts, in several instances, embodied option clauses exercisable subsequent to June 30, 1927. By this method were purchased:

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56 fighters,
32 training planes,
36 observation planes,
48 torpedo planes,
25 engines,
and corresponding allowances of spare parts.

The advantage of this procedure is obvious in that prices were secured based on quantities, the combined requirement for 1927 and 1928, and on continuous manufacture. The normal negotiation and clerical work on the part of the Bureau for at least five contracts were eliminated.

It is not reasonable to assume that this same procedure can be followed in the future to the same extent that it was for the fiscal years 1927 and 1928. It is conservatively estimated, however, that it was possible to procure for the same aggregate funds, during these two fiscal years, approximately $875,000 worth more equipment than would have been obtained had the option method of purchase not been taken advantage of.

COMMANDER GARLAND FULTON, C.C., U.S.N.: Captain Land's paper barely mentions the "lighter-than-air" or airship branch of naval aeronautics. Relatively few airships are in existence and airship work as it stands at present is very properly regarded as experimental in character, and is so handled. The volume of work and amount of money devoted to airships is but a fraction of that which is devoted to airplanes, but it may not be amiss to point out very briefly some of the lines along which airship development has been proceeding.

A very satisfactory design of a 6,000,000 cubic foot airship has been procured and negotiations are under way looking towards a contract for the construction of the first of the two airships of this size that have been authorized by Congress. Methods have been developed through which the stress analysis of an airship can be carried through with a very high degree of mathematical accuracy. The increase in size will permit these new airships to be made very much more rugged than previous airships.

Carrying, launching and landing airplanes on large airships is being studied carefully. The problems connected with landing and handling large airships on the ground and into and out of sheds are being attacked vigorously with promise of good success being attained through possible reductions in ground crew and also through increased facility and safety in handling the airships.

Development of engines especially suitable for airships is under way. An improved aluminum alloy, strongly resistant to corrosion, has been developed and appears to hold much promise.

A novel type of "metal-clad" airship has been under construction for a year. It is too early to forecast what the outcome of this experiment will be.

Abroad, Great Britain has been pushing ahead with her two 5,000,000 cubic foot airships, which will be flying within a year. The new German-built airship will be ready in the same period. The successful completion of these airships, intended for long overwater voyages, should do much to accelerate airship development in the United States.

COMMANDER E. M. PACE, JR., C.C., U.S.N.: The excellent performance of our aircraft is not to be measured solely in terms of that performance, for in obtaining this performance primary consideration was given to incorporating the military features required and an arrangement of the parts in such a way as most effectively to meet the peculiar problems of naval aviation. Specifically, I have in mind such restrictions as the shipboard operation imposes on the size of airplanes, low limit on landing speed for carrier operation and for operation in heavy seas, arrangement of structure and placing of personnel to attain requisite visibility and arc of fire for use of armament, and other items which it would probably not be advisable to go into.

LIEUTENANT WALTER S. DIEHL, C.C., U.S.N.: The Navy has made arrangement to have the Handley Page slots and flaps incorporated in a service type airplane for comparative tests, the results of which may have great influence on future design. At the request of the Bureau of Aeronautics, wind tunnel and flight tests are being made on the various methods of "boundary layer" control, by the National Advisory Committee for Aeronautics. By the use of boundary layer control, wing lift may be greatly increased and drag decreased.

CAPTAIN LAND stated that racing, while expensive, tends to improve the art of aviation for the racing plane of today is the fighting plane of tomorrow.

Test of Pulverized Coal as Applied to Scotch Marine Boilers

By Carl J. Jefferson and Commander Joseph S. Evans, U. S. N.

This paper is published on page 660 of this issue.

DISCUSSION

ERNEST H. PEABODY, president of the Peabody Engineering Corporation, showed on the screen a photograph of the boiler with the type of burner which was actually tested pointing out the simplicity of the arrangement. He stated, in passing, that Scotch boilers have been fired with pulverized coal under conditions where the entire fireroom was filled with an extension furnace extending sometimes even up into the fidley. Mr. Peabody also emphasized the liberation of British thermal units per cubic foot of furnace volume given on page 11 as about 59,000, including the corrugated furnace and back connection. If the back connection is not included, the figure is 141,600 B.T.U.'s per cubic foot which is believed to be a new record for pulverized coal. If the combustion was practically complete in the corrugated furnace, the actual performance is represented by this figure. He stated that he had always advocated including the entire combustion furnace volume in estimating the combustion rates and as there are probably corners in the corrugated furnace in the front that are not used he felt that this figure is not representative of the actual results. Referring to the distributor, he stated that the problem of dividing a stream of carrier air and pulverized coal is recognized as one of the most difficult to meet in practice. It is comparatively easy to divide a stream into an even number of equal parts but it is very difficult to divide it into an odd number of equal parts. Referring to the pulverizer, he pointed out that the necessity for fine pulverization is obvious and that this was obtained in the tests at Philadelphia but raised the question of what is likely to happen with the low rate pulverizer on board a vessel which is rolling at sea? He stated that he anticipated that when the ship is rolling there is going to be some unevenness of feed to the burners resulting in at one moment not enough coal and too much air and in another instant too much coal and smoke.

THOMAS B. STILLMAN, the Babcock and Wilcox Company, New York: One point that will undoubtedly prove of great importance in the future of pulverized coal on shipboard is the fusing point of the ash in the coal. When this is lower than the average furnace temperature there is a tendency for this ash to fuse to a plastic condition in the furnace instead of passing through the same as a light powder, and it would undoubtedly be well for the future of the art to obtain some comparative information with different grades of ash in coals at the Fuel Oil Testing Plant to de-

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termine the fusing points below which it would not be desirable to operate, with this type of boiler.

At the bottom of page 11 the statement is made that "The unaccounted for loss consists chiefly of radiation losses." In the case of a Scotch boiler which is thoroughly lagged for most of its exterior surface, this is not liable to be true, unless the total "unaccounted for" losses are extremely low. For example, if we assume that the average temperature of the surface of the boiler exposed to the fire-room is 250 degrees F., the total B.t.u. radiated per hour from one square foot of surface would be 490. Assuming the surface exposed to the room to be approximately 870 square feet, the total B.t.u. radiated per hour from the exterior of the boiler will be in the neighborhood of 427,000. On this basis the heat radiated for test No. 1 will be 2.45 percent; for test No. 2, 2.16 percent; for test No. 3, 1.86 percent; for test No. 4, 1.63 percent and for test No. 5, 1.52 percent.

In none of the oil burner tests referred to in this paper, which were run on this boiler was the sum of the radiation and unaccounted for losses less than about twice the values given above, and the averages given in plate No. 7 were considerably higher than this, clearly showing that the unaccounted for losses in the form of unburned hydrocarbons, etc., going up the stack when burning oil were very important items. In the case of pulverized coal there are practically no hydrocarbon losses, the losses of this type that do occur being in the form of unconsumed carbon. It is, therefore, a somewhat doubtful procedure to apply the hydrocarbon losses of the oil fuel tests to the pulverized coal tests.

Although it is manifestly impossible to make an accurate division of the total "unaccounted for" losses in a pulverized coal test, if such a division is desirable, we believe it will be more accurate to divide these losses into radiation and unconsumed carbon. If this is done for the five tests reported herewith, the following tabulation will be secured:

Test No.	No. 1	No. 2	No. 3	No. 4	No. 5
Percent loss due to unconsumed carbon	11.90	10.37	10.81	11.74	14.24
Percent loss due to radiation	2.45	2.16	1.86	1.63	1.52
Total percent loss due to radiation and unconsumed carbon	14.35	12.53	12.67	13.37	15.76

It is not believed by the writer that an improvement in the distributor, as referred to in the third paragraph on page 12, would appreciably affect the boiler efficiency mentioned in that paragraph. There are not enough variations in the furnaces as reported in the tests to account for any such improvement. The place to look for an improvement in efficiency of the magnitude noted is in the more complete combustion of the carbon and not in the slight variations which occurred in the efficiencies of the different furnaces.

Near the bottom of page 12 and on Plate 9 a comparison is made between the boiler efficiencies secured with oil burners and the pulverized coal burners on this same boiler. The comparison as made is not quite fair to the oil burners, as attention is not called to the fact that none of the oil burner tests was run with an air heater on the boiler, whereas the pulverized coal tests reported herewith were all made when an air heater was in use. Based on the data of the pulverized coal tests, the additive efficiency due to this air heater was on the average in the neighborhood of 3 percent, so that to make a direct comparison with the oil tests this 3 percent should be added to the oil results. This does not allow for the improved efficiency of combustion which would probably occur due to the use of the air heater in reducing the hydrocarbon loss which was occurring with the oil burners.

In the next to the last paragraph on page 12 attention is called to the fact that the most satisfactory efficiency curve secured with oil was obtained with a burner having positive control (in the form of individual fans) of the air supply to each furnace, this being given as the probable reason why this burner excelled the other ones. This statement would hardly be conclusive in view of the fact that two of the other burners tested had a very similar type of individual air control and one of these gave about as poor a set of efficiencies as any burner ever tried on this boiler.

The last paragraph on page 12 and the first on page 13 calls attention to the fact that the low efficiency secured on test No. 5 was probably due to the fact that the boiler had been in operation for 200 hours previous to this test, and that, therefore, the boiler was probably pretty well scaled up and correspondingly inefficient. This conclusion is not confirmed by the test results, as it may be noted that the average gas temperature leaving the air heater of test No. 5 was only 6 degrees F. higher than for test No. 4, this difference in gas temperature accounting for approximately ⅙ percent boiler efficiency, this value being far from the 3 percent difference occurring in the actual tests. Undoubtedly the cause of the falling off in efficiency occurring in test No. 5 was due to the high rate of combustion being attempted in the furnace volume available, resulting in a decided increase in the unconsumed carbon loss up the stack. This is confirmed by the fact that the total unconsumed carbon and radiation loss occurring on test No. 5 was 15.76 percent as against 13.37 percent for test No. 4.

CHARLES F. BAILEY, engineering director, Newport News Shipbuilding and Dry Dock Company, expressed the belief that pulverized coal can be applied to a very large extent shortly to cargo vessels fitted with Scotch boilers but for passenger vessels the problems are somewhat more complicated because of the fly ash which may be emitted from the stack and because of the coal dust which must be eliminated from the machinery space and throughout the ship. He stated that this development will mark a real epoch in marine engineering, corresponding to the outstanding achievements of the past which have been carried out by the late Admiral Melville, Mr. Sperry and Rear Admiral D. W. Taylor.

W. W. SMITH, chief engineer of the Federal Shipbuilding Company, called attention to the remarkable progress which has been made in the use of pulverized coal in land plants during the last 5 years, stating that even in land plants the development of pulverized coal is in an immature state while for marine plants it is in its infancy and that remarkable progress may be expected in this direction. Pulverizers he thought are subject to improvement as those used in these tests were rather large and bulky for use on board ship. He predicted that their weight and size would be reduced. The efficiencies shown in Fig. 10 compare favorably with oil, in fact they are higher than with oil except with one type of burner. In general, the same boiler efficiency can be obtained with pulverized coal as with oil. The air heater used in these tests had a surface less than 25 percent that of the water heating surface whereas it is customary to use an air heater of 40 or 45 percent and with a larger air heater a higher efficiency may be expected, say 80 percent, which was compared with about 65 percent for hand firing consequently the saving in fuel due to pulverized coal over hand firing will be very material. The saving in labor of firing is also important but labor saving devices should be adopted for handling the coal in the ship. The ships on the Great Lakes which are stoker fired have conveyors and hand labor is not required. Mr. Smith agreed that this is an epoch-making development and that the field for its application is very large both on the ocean and on the Great Lakes.

JOHN L. BOGERT, consulting engineer, pointed out that the literature on pulverized fuel is very extensive and referred to the fact that ten years ago a British steamship used pulverized fuel in one of its boilers. Comparing the fuel consumption of motorships and pulverized coal burners, estimating one pound of pulverized coal sufficient for a

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brake horsepower, he stated that a Diesel motorship would burn 150 tons of oil on a trip across the Atlantic whereas pulverized coal burners would have to carry 183 tons more of coal than the motorship would of oil.

F. G. PARKER, The Engineer Company, emphasized the importance of the transportation factor in burning pulverized coal. In his estimation the working out of satisfactory conveying apparatus for handling the coal is one of the biggest problems involved.

F. M. GIBSON, on the other hand, stated that the most important factor is the burner and he paid a tribute to the equipment manufacturers for their pioneer work in solving this problem.

MR. DAVIDS, of the Federal Shipbuilding Company, asked for the following information: 1. The cost of installation on the S.S. *Mercer*. 2. Restrictions as to space occupied for types of ships. 3. Cost of operation. 4. Amount of coal used on the trip of the *Mercer* from Baltimore to New York. 5. Cost of changing over a 6,000 gross ton ship from oil to coal.

W. J. A. LONDON expressed the opinion that the correct design of mill has not yet been developed. While the tests showed a remarkable performance in fineness of the pulverized coal the power absorbed by the mill was 18 kilowatts for both the 1,200-pound and the 2,000-pound rates showing that at low loads the power that should go to powdering coal is used in powdering up the balls. He stated that the impact mill shows a lower power consumption even up to the highest rates. In land practice he stated that it is quite common to get a ton of coal for 15 kilowatts or 22 horsepower. Three points are to be considered: First, weight; second, economy, and third, noise. The impact mill he said is the lightest, most economical and eliminates noise and he felt that further consideration should be given to the possibilities of the impact mill.

MR. SCHRECK, of the Doherty Research Company, New York, called attention to a single cylinder 80 horsepower Diesel engine in Germany which is run on pulverized coal and which has been furnishing the power for a factory since 1921. The cost, including pulverizing is one-third the present cost of running a Diesel engine on fuel oil. In using pulverized coal in Diesel engines, the important question is ash content of the coal which, in the tests mentioned in the paper, is about 5 percent. There is very little coal in this country, he said, which has only 5 percent ash content, generally it is much higher. He asked first, if the coal used for these tests was specially prepared —that is, washed at the mines and, second, can you use run-of-mine coal or do you expect trouble with molten ashes in the furnaces?

JOHN REID, naval architect and engineer, New York, brought up the question of the scope for pulverized coal. Two years ago a 10-knot 10,000-ton steamship was fitted out to get the consumption with coal, hand fired, down as low as possible. The result was 28 tons a day. Today this is down to 25 tons and pulverized coal would bring it appreciably lower, but how much will this cost? The installation on the *Mercer* cost around $35,000 which cannot be made up in two or three years' savings. Figures quoted from a paper giving the results of 6 voyages of well equipped steamers across the Atlantic showed that the average boiler efficiency did not rise above 65 percent. Pulverized coal should give 75 percent efficiency in average service. After spending a lot of money, what do you get? Perhaps one-half to three-quarters of a knot on your ship. Stokers fix the speed of the ship. The human element is the critical factor. The success of pulverized fuel will depend upon the handling of the air for combustion.

B. E. MEURK, superintending engineer, Isthmian Steamship Lines: Aside from the necessity of obtaining good mills for pulverization of coal, correct distribution of fuel and air and a short and effective flame in the furnace, it is also necessary to maintain a low enough temperature in the furnace to cool the ash beyond the fusing point before it has time to touch the walls or bottom of the furnace to prevent a deposit of slag. The Scotch boiler has an advantage in this respect due to the fact that the completely water cooled furnace will absorb the heat units at a greater rate than in the ordinary watertube boiler where the furnace is insulated by brick work. Comparing the Scotch with the watertube boiler it appears that coal of a greater variety and quality can be used in the Scotch boiler. Unless the present watertube boiler is redesigned so that the radiating surface of the brick work can be displaced by water walls and also eliminate the brick baffle underneath the furnace, it does not appear to be feasible to burn pulverized coal with an ash of a low fusing point. The furnace temperature can of course be lowered somewhat by decreasing the rate of combustion or by using more excess air which is detrimental to the horsepower output and efficiency.

Pulverized Coal Tests of a Marine Watertube Boiler

By Thomas B. Stillman

This paper is published on page 669 of this issue.

DISCUSSION

PROFESSOR LAWRENCE B. CHAPMAN, Massachusetts Institute of Technology: The tests of the watertube boiler show efficiencies appreciably higher than obtained with the Scotch boiler. Yet due to the high percentage of excess air used with the watertube boiler the loss due to the stack gases is slightly higher with this boiler than with the Scotch boiler. Other losses being equal with the two boilers this would give the Scotch boiler the higher efficiency.

A comparison of the heat balances for the two boilers will show that the Scotch boiler has a loss of around 7 or 8 percent due to "loss in combustible of ash and flue dust." This loss is not present with the watertube boiler. The percentage of combustible in the ash and flue dust ranges generally between 7 to 16 percent with the watertube boiler tests, while it is 35 percent with the Scotch boiler. If this loss could be eliminated in the Scotch boiler with the same amount of excess air as used in the tests, it would show an efficiency around 84 percent. The watertube boiler would also show an efficiency of around 84 percent, if the excess air were reduced to that used with the Scotch boiler. These efficiencies are as high as one would expect with fuel oil under the best of conditions and of course far greater than possible with hand firing.

I would like to inquire of the authors if they can give any further information on this point and if there is anything peculiar about the Scotch boiler or any special conditions existing during the tests that would lead them to believe that this loss can not eventually be reduced.

Difficulties with ash fusing were mentioned in connection with the watertube boiler tests but no mention was made of this in connection with the Scotch boiler tests. With the watertube boiler the percent of excess air was kept high, apparently to reduce the furnace temperature in order to protect the brick work. This caused a loss in boiler efficiency as already noted. I believe that the final solution of the problem of burning pulverized coal with marine watertube boilers will be the adoption of

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water cooled walls and the elimination of refractory brick work as has been done almost universally in pulverized coal burning on shore.

The power used by the pulverizing units was high in both boiler tests. This need cause no concern, however, if electric motors are used and the electric power is produced efficiently; or if the units are driven by a steam engine or turbine then the exhaust steam can be used advantageously for feed heating.

An interesting and important point brought out by Mr. Stillman is the question of maneuvering a ship using pulverized coal. It will be interesting to know what provisions have been made on the *Mercer* to take care of the feeding of pulverized coal while maneuvering.

As has already been pointed out, the real value of pulverized coal from the shipowner's point of view is more the elimination of hand firing than the increase in boiler efficiency.

W. W. SMITH: If the proper kind of coal is used, handling the ash will be a very simple problem. This is based on the assumption that the ash will not fuse. The ash is very soft and it is easy to pull it out of the furnace. It has to be pulled out only once a day which is a great improvement over cleaning fires every watch. The fusing point of the ash must be above 2,400 or 2,500 degrees which means that not every kind of fuel can be used with pulverized coal equipment. On page 9 the author refers to the considerable amount of steam required for pulverizing coal. Power for the exhauster, or at least part of it, should be deducted as the exhauster supplies part of the air for combustion. The rate of 30 pounds per horsepower is excessive for any kind of modern ship. With a rate of 9 or 10 pounds the percentage would be about 2½ instead of 7½. With increased efficiency of this apparatus this figure may be expected to be reduced in the future. I believe the impact mill has greater possibilities for future development. A mill whose speed is a mean between the very highest and the very lowest would be most suitable for use on board ship. The boiler on which these tests were made was a very small one, making it more difficult to burn pulverized coal efficiently. With a larger boiler and larger furnace the results would be improved. Generally speaking with a large boiler the efficiency with pulverized coal should be about the same as with oil.

In order to regulate the furnace temperature to the best advantage, water cooling may or may not be required. The quality of fire brick used for lining must be of the highest grade with a fusing point above 3,300 degrees. The size of the furnace should be as large or larger than that for oil; that is the heat liberation per cubic foot should be between 50,000 and 60,000. By using an air heater in combination with a boiler we estimate that we can get an average efficiency in service of 85 percent for the boiler unit.

Pulverized coal can be applied to any oil burning ship today and if a new ship is built for burning oil or for burning pulverized coal it can be changed to the other fuel if the economic conditions make it profitable to do so. I consider it entirely practicable to install a pulverized coal equipment on a ship at the present time. The cost is important but with labor-saving devices for handling the coal the cost of labor should not be more than that on an oil burning steamer. The cost of fuel per shaft horsepower for the coal burning steamer would be about 0.2 of a cent and for a Diesel installation about 0.3 of a cent, making a ratio of about 1.5. The ratio of first cost is about 1.4 to 1.5 and the ratio of weight about 1.6 to 1.7.

A. MARKS, Doherty Research Company: In the tests on the watertube boiler, without any modification of the firebox a fuel was put into it for which it was not designed, thus spoiling the value of the test. Many boilers are running today which are not designed for their jobs. At least 50 percent of the boilers cannot be forced without the production of, and without an enormous loss in, carbon monoxide going up the chimney.

DONALD J. MOSSHART, stoker department, Westinghouse Electric and Manufacturing Company: Figures obtained on land for pulverizing coal in small size installations run in the neighborhood of 50 kilowatts per ton, meaning a loss in efficiency of 3½ percent to grind up the coal. In land practice you must have a hot furnace to get economical combustion in a small space, consequently if you try to hold furnace temperatures down to accommodate the ash you are going to knock your efficiency out. Today it is nip and tuck between stokers and pulverized coal on land. In a small installation the stoker has it all over pulverized coal. If you put a stoker on a boat, what do you get? You do not have to worry about maneuvering. There is no fooling around with burners. You do not have to worry about whether your fire is going out or not. You do not need to worry about air because in the mechanical supply of fuel the air supply is taken care of and it is not under the control of firemen. You have capacity, you can burn 40 or 50 pounds of coal per square foot with economies that are practically duplicates of pulverized coal economies. If you lose a boiler, you do not have to worry about combustion space, you can run the other boilers up. Your coal character problem is eliminated, because the stokers burn any kind of bituminous coal. Since August, 1927, there has been in service on the Great Lakes a 15,000-ton limestone freighter having two Babcock and Wilcox boilers fired by Station W stokers. From data available, the efficiency is around 83 percent. The regular schedule is maintained and there is ample capacity left over.

JOSEPH J. NELIS, vice-president, Foster Marine Boiler Corporation: On page 8 Mr. Stillman refers to the fact that slag is sticking to the lower row of tubes. You would naturally expect that in a small brick set boiler; that same boiler, water cooled all over, would not have had any trouble with slag from that coal.

What becomes of the ton or more of coal in the ball mill when we have to maneuver? In an impact mill we shut our feed off and in a couple of seconds the mill is empty. Figures from 10 Shipping Board boilers which have had impact mills on them for 3 years show the cost of upkeep, after running 15,000 tons of coal, about 6½ mills per ton of coal. The impact mill will not be affected by rolling and pitching. It is rapidly coming in in shore plants and it is believed that it will come into more general use in ships.

GEORGE A. ORROK: Powdered coal on a steamship to my mind depends not so much on the fact of its being powdered coal but on the fact that for that purpose you must have conveyors and bunkers so arranged that the coal can be brought from the powdering plant to the furnace without any hand labor. If this can be arranged, the handling force can be cut down even below what is possible with an oil-fired ship. In some of the modern stations we get a shaft horsepower on 0.6 pound of coal in an ordinary steam plant.

CARL J. LAMB: Some fuels, beyond question, such as the lignite coals, which require relatively small power for pulverization, and those coals having ash of high fusing temperatures, are well adapted to pulverized fuel installations. Mr. Stillman says that the ash fusing point in degrees F. should be above furnace temperature. At the same time, furnace temperature must be high if high combustion efficiency and capacity are to be maintained. This indicates that better grades of fuels must be used when burning powdered coal under marine watertube boilers. On the other hand, there is no bituminous coal used ashore or at sea

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which cannot be burned efficiently and reliably by means of proper stokers, regardless of the ash fusing point of temperature. At present, for marine purposes, the application of stokers is limited to watertube boilers. It is interesting, in this connection to note that a marine type stoker can be applied to watertube boilers without complicating the ship's structure or increasing fire room space any appreciable extent, the only material change, as compared with hand fired boilers, being that the overall height will be increased about 18 inches.

Under the heading of efficiency, Mr. Stillman has stated that consistently higher boiler efficiencies may be secured with pulverized coal, properly handled under a boiler, than with any other method of firing this fuel. All factors being considered, we believe this statement is open to question and debate. For those who are interested, we call attention to the annual reports on pulverized fuel, and stokers, put out by the N.E.L.A. for 1927.

Mr. Stillman mentions a figure of 25 horsepower per 1,000 pounds of coal burned as being required for pulverization in the case of his pulverized fuel installation. For the same size and type boiler, but equipped with underfed stokers, it is safe to say that less than 3.5 kilowatts (which incidentally includes the power required by the forced draft blower) will be required to burn the coal very efficiently.

With the Scotch boiler, looking at table 1, top of page 17, column 5, we find approximately 10.5 kilowatts per 1,000 pounds. This figure does not include the power required for the secondary air, which will be about 3 kilowatts per 1 inch air pressure at the fan outlet. 13.5 kilowatts is the corresponding total equivalent to about 18 horsepower per 1,000 pounds of coal burned.

From the above figures it would appear reasonable to assume that, since stokers are out of the question on Scotch boilers at the present time, pulverized fuel is particularly well adapted to them. It would appear further, however, due to much less power required, greater range as to kind of coal burned and due to greater flexibility of control (the ratio between full rating and minimum rating is 6 to 1) stokers are probably better adapted to watertube boilers than are pulverized fuel installations.

Since August, 1927, the S.S. *Carl D. Bradley*, a 15,000-ton bulk carrier on the Great Lakes, has been operating satisfactorily with Babcock and Wilcox boilers served by underfeed stokers. Test results show 83 percent boiler efficiency.

CARL J. JEFFERSON stated with regard to the action of the ball mill at sea that the *Mercer* encountered heavy weather coming from Baltimore to New York and that while the balls cascaded faster there was no difference in the grade of fuel. He concurred with Mr. Stillman that the method of determining the amount of combustible and fly ash was open to question but he disagreed with Mr. Stillman's figures on radiation, stating that the Scotch boiler has at least 75 percent outer shell exposed without any insulation which results in rather heavy radiation. The drop in efficiency at the 2,000-pound rate he felt was due to fan trouble more than anything else. As to the question of impact versus ball type pulverizers he called attention to the fact that the chunks of iron, pieces of pipe, spikes, brake shoes, etc., which were taken out of the ball mill would have smashed an impact pulverizer. The success of the 240-hour test was not due to some particular burner, piping or mill but to a combination that worked. You must have super-fines for a wide range of coal and for a wide range of capacities. You must have turbulence and your piping must be designed so that you have the right velocities throughout. We had a combination that worked. You cannot keep fires on 40 mesh coal, you must have super-fines that go through a 300 mesh. With pulverized coal we are trying to put brains in the fire room instead of brute force. The type of boiler that approaches the boiler we are going to use in future for pulverized coal is now on the *Ile de France*.

COMMANDER JOSEPH S. EVANS: Both the transportation and the distributor must work together. The distributor must break up all stratification of the coal and not only distribute equal amounts of coal to each furnace but also an equal amount of the super-fines. As to the power for the ball mill we could find no difference when operating at 1,200 pounds and at 2,000 pounds. I doubt very much whether there are more than 500 pounds of coal in the mill from the feeder to the burners at any one time. The *Mercer* undocked from Baltimore and docked in this harbor under powdered coal. All maneuvering was under powdered coal and in docking at New York 32 bells were given from the bridge to the engine room in an hour and two minutes. A satisfactory pulverizer is one that gives a large percentage of very fine coal. The impact mill gave us a coarse coal which we could not burn; new paddles were installed but the mill was slightly out of balance and the noise prohibitive. It took two days to correct the balance, something which cannot be done on board ship, especially if the ship happens to be rolling. As for taking the *Mercer* to sea, I am perfectly willing to take the ship to sea and maneuver all of the time under the present powdered coal installation. The installation must not be considered as final; it is a first experiment but I think it has shown that the burning of powdered coal in small furnaces of marine boilers is satisfactory.

THOMAS B. STILLMAN: Mr. Smith referred to the boiler and the furnace as being a relatively small unit. The boiler has a heating surface of 2,755 square feet and the average of all watertube boilers in the Emergency Fleet Corporation is in the neighborhood of 2,900 square feet. A moderately good brick is satisfactory—it does not need to go up to 3,300 degrees with a good ash; with poor ash, no brick will save you. The finer we go in pulverization the better off we will be.

CAPTAIN R. D. GATEWOOD: The single important fact that has been brought out this morning is that a pulverized coal marine installation on a man-sized ship has gone to sea and come into port and been maneuvered out of port and into port and that there has been little or no grief in connection therewith. The *Mercer* installation cost too much; the Diesel installations have cost a great deal more than too much; while the Diesel installations do not give very great promise of very material reduction in cost of installation and engine, on the other hand our very limited experience thus far with pulverized fuel gives great promise of very material reductions in cost. A new *Mercer* installation has been worked out at less than two-thirds or more nearly one-half the cost of the present installation. In my opinion the hand labor cannot be eliminated on an existing ship but there is no reason why future ships cannot be so designed that the handling and distribution of the coal will be very much simpler than it is at present. It seems to me that a pulverized coal installation can be made on board a ship for about one-sixth the cost of a Diesel engine. We ought to have in this country within eighteen months not less than 200 successful marine pulverized fuel installations.

Test of a Two Cycle, Double Acting Marine Diesel Engine

By Ernest Nibbs and Stephen A. Gardner

An abstract of this paper will be published in an early issue.

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The Engines of the U. S. Shipping Board Diesel Conversion Program

By Captain R. D. Gatewood (C.C.), U. S. N.

ABSTRACT

There have been completed for the Shipping Board Diesel conversion program twelve engines of the following types and manufacture: Two Worthington, two-stroke cycle, double acting; three McIntosh and Seymour, four-stroke cycle, single acting; one McIntosh and Seymour four-stroke cycle, double acting; four Busch-Sulzer two-stroke cycle, single acting; one Hoovens, Owens, Rentschler, two-stroke cycle, single acting; one McIntosh and Seymour, four-stroke cycle, double acting; one New London Ship and Engine Company, two-stroke cycle, double acting. The last two engines are of the M.A.N. design.

The Worthington engines are of 2,900 brake horsepower, having four double-acting cylinders, 28-inch diameter and a stroke of 40 inches, operating on compressed air fuel injection and having a four-stage compressor attached to and driven by the main engine. Scavenging air is furnished by a pump, driven by the main engine through double, helical herringbone gears. The pump has two double-acting cylinders placed in tandem.

The completed engine weighs 740,443 pounds. The overall dimensions are 41 feet 6 inches long, 16 feet wide and 28 feet high above the base.

The first of these two engines successfully completed a thirty-day continuous shop test at full power, the results of which showed a fuel consumption of 0.473 pound of oil per brake horsepower when corrected to a standard low heat value of 18,500 British thermal units, and a mechanical efficiency of 72.48 percent.

The second engine had a shop test of twenty-four hours on full power, which demonstrated a fuel consumption of 0.446 pound per brake horsepower corrected, and a mechanical efficiency of 71.1 percent.

The two Worthington engines were installed in the vessels *Tampa* and *Unicoi*. The *Tampa* completed a sea trial successfully and proceeded immediately to Savannah to load cargo, from which port she sailed fourteen days later on her maiden voyage to Bremerhaven. The outbound passage of 4,100 miles was made without a stop at an average speed of 11.8 knots and a fuel rate of 0.467 pounds of oil per brake horsepower hour and a daily consumption of 14.19 tons. On the inbound passage very heavy weather was encountered, but the 3,200 miles from Antwerp to Boston were made without a stop at an average speed of 10.13 knots and a daily consumption of 11.84 tons.

The *Unicoi* after a successful sea trial proceeded to New Orleans and Galveston to load cargo; she sailed from the latter port direct to Venice, Italy, completing the passage of 6,540 miles without a stop in 23½ days at an average speed of 11.61 knots on a daily fuel consumption of 13.76 tons, or a rate of 0.475 pound per brake horsepower hour for all purposes. The return passage from Naples, with a stop at Palamos, to Philadelphia, a distance of 4,518 miles, was made at an average speed of 11.5 knots and a daily consumption of 13.4 tons of fuel or a rate of 0.46 pound of fuel per brake horsepower hour for all purposes.

The single-acting McIntosh and Seymour engines are of 2,700 brake horsepower, having six cylinders 32 inches in diameter and a stroke of 60 inches.

The air for fuel injection is furnished by an independent compressor unit having four power cylinders 17 inches in diameter and a stroke of 24 inches, operating at 200 revolutions per minute. Three three-stage compressors are operated by the engine crank shaft. The compressors supply injection air for both the independent unit and the main engine.

	Pounds
The completed main engine weight is.....	827,120
The completed independent compressor weight is ..	139,150
Making a total weight for the main propelling unit of	966,270

The overall dimensions of the main engine are: Length, 44 feet 2 inches; width, 17 feet 2 inches; height, 30 feet 6 inches above the base seating.

The overall dimensions of the independent compressor unit are: Length, 31 feet; width, 10 feet 3 inches; height, 13 feet above base.

The first of the three engines successfully completed a shop test of thirty days continuous running at full power, the results of which show a fuel consumption of 0.428 pound per brake horsepower hour corrected for a standard low heat value of 18,500 British thermal units, and a mechanical efficiency of 81.37 percent, not including compressor unit.

The second and third engines had shop tests of twenty-four hours duration each, which demonstrated a fuel consumption of 0.416 and 0.417 pound per brake horsepower hour respectively, when corrected to the standard low heat value of 18,500 British thermal units and a mechanical efficiency of 81.45 percent and 77.1 percent respectively, compressor not included.

These three engines were fitted in the vessels *West Honaker, West Cusseta* and *Crown City.*

The *West Honaker,* after a successful sea trial, proceeded to Charleston, S. C., to load cargo, from which port she sailed on her maiden voyage direct to Bremen, Germany, and return to New York. While a stop of six hours was necessary on the return voyage due to fog and heavy weather, no engine trouble was encountered. The outbound passage was made at an average speed of 10.66 knots on a daily consumption of 13.79 tons and the inbound passage at an average speed of 11.73 knots and a daily consumption of 11.85 tons, or a fuel rate of 0.445 pound per brake horsepower hour for all purposes.

The *West Cusseta,* fitted with the second engine, after a successful sea trial loaded at New York, from which port she sailed direct to Australia via the Panama Canal, returning over the same route. The maiden voyage of this vessel covered a distance of 20,613 miles, the only engine trouble encountered being due to some foreign objects fouling the piston cooling tubes on one cylinder, after replacing which no further trouble was encountered throughout the entire voyage. The entire voyage was made at an average speed of 11.44 knots on a daily consumption of 11.78 tons of fuel and a fuel rate of 0.455 pound per brake horsepower hour for all purposes.

The *Crown City,* fitted with the third engine, after a successful sea trial loaded at New York for Australian ports and return through the Suez Canal and the Mediterranean, making an around-the-world voyage, which at the time of writing has not been completed.

The McIntosh and Seymour double-acting engine is of 2,700 brake horsepower, having four cylinders 32 inches in diameter with a stroke of 52 inches. The air for injection is furnished by a three-stage compressor attached to and driven by the main engine.

The shop test of thirty days continuous running demonstrated a fuel rate of 0.417 pound per brake horsepower hour and a mechanical efficiency of 76.5 percent.

The engine weight completed is 765,000 pounds and the overall dimensions are: Length, 32 feet 6 inches; width, 14 feet 3 inches; height above base, 33 feet 3 inches.

The engine is in course of installation in the *West Grama.*

The four Busch-Sulzer two-cycle engines are of 3,000 brake horsepower, having six single-acting cylinders, each 30 inches in diameter with a stroke of 52 inches. The air for injection and for scavenging is furnished by a compressor

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and a scavenge pump attached to and driven by the main engine.

The first of these engines completed was given a thirty-day continuous shop test at full load, the results of which show a fuel rate of 0.432 pound per brake horsepower hour and a mechanical efficiency of 74.47 percent.

The second, third and fourth engines were tested in the shop for a period of twenty-four hours and demonstrated fuel rates and mechanical efficiencies as follows:

Second engine—fuel rate, pounds per B.H.P. hour, 0.423. Mechanical efficiency, 70.3 percent.
Third engine—fuel rate, pounds per B.H.P. hour, 0.415. Mechanical efficiency, 75.6 percent.
Fourth engine—fuel rate, pounds per B.H.P. hour, 0.414. Mechanical efficiency, 76.8 percent.

The completed weight for one engine is 850,000 pounds. The overall dimensions are: Length, 48 feet 4 inches; width, 13 feet 3 inches; height above base, 26 feet 1 inch.

The first of the four engines was fitted in the *City of Rayville,* which, after a successful sea trial, loaded at New York, from which port she sailed in the Australian trade around the world and has not completed the voyage to date.

The second engine was installed in the *Sawokla,* which, after a successful sea trial, proceeded to Philadelphia, from which port she sailed in the South American service to Buenos Aires and return to New York. The voyage of 12,977 miles was completed with an average speed of 11.6 knots on an average daily consumption of 14.46 tons of fuel, or a fuel rate of 0.486 pound per brake horsepower hour for all purposes. The only engine trouble experienced was a piston cooling tube carried away and a defective piston casting, necessitating renewal of these parts.

The third engine was installed in the *City of Dalhart,* which has passed a successful sea trial and is at time of writing in New York loading cargo for the Australian service.

The fourth engine is in process of installation in the *Yomachichi.*

The Hooven, Owens, Rentschler engine, known as the Hamilton M.A.N. engine, is of 3,300 brake horsepower, having four double-acting cylinders, each 27½ inches in diameter with a stroke of 47¼ inches. The air for injection is furnished by a three-stage compressor attached to and driven by the main engine, as is also the twin-cylinder, double-acting, scavenging pump.

Upon completion this engine was given a shop test of thirty days continuous running, the results of which demonstrated a fuel rate of 0.444 pound per brake horsepower hour, corrected to a standard low heat value of 18,500 British thermal units and a mechanical efficiency of 74 percent.

The completed engine weighs 871,000 pounds and the overall dimensions are: Length, 42 feet 6 inches; width, 16 feet 8 inches; height above base, 30 feet 4 inches.

This engine is now in course of installation in the *Seminole.*

The New London M.A.N. engine is of 3,300 brake horsepower, having four double-acting cylinders, each 27.55 inches in diameter with a stroke of 47¼ inches. This engine is of substantially the same design as the Hamilton M.A.N. engine, only varying in some minor details.

The thirty-day continuous shop test demonstrated a fuel rate of 0.445 pound per brake horsepower, corrected to a standard low heat value of 18,500 British thermal units and a mechanical efficiency of 72.5 percent.

The test on this engine was made at an average brake horsepower of 3,680 and 115 revolutions per minute. While the designed conditions were 3,300 brake horsepower at 95 revolutions per minute, the change to the power and speed conditions maintained on the test were occasioned by the fact that the engine worked considerable at the designed speed, which was caused as far as could be determined by the foundations in the shop on which the engine was set up. The engine ran steadily and quietly at the conditions stated and completed the thirty days run without a stop.

The paper contains summary log sheets covering the thirty-day tests on each of the above engines.

DISCUSSION

PROFESSOR EVERS BURTNER, Massachusetts Institute of Technology: When curves of total fuel consumption vs. brake horsepower are plotted for the engines tested, it will be noted that the average no load fuel consumption for these engines is slightly under 10 percent of the full load consumption. (A similar value is shown by a study of other oil engine tests.) This indicates that the power required by the direct connected auxiliaries decreases with a decrease in load. Reference to the tests shows that the power required by the attached scavenging pumps of the two cycle engine is approximately directly proportional to the engine brake horsepower while the power absorbed by the injection air compressors decreases more slowly with decrease in load.

For the engines under discussion the fuel consumption pounds per brake horsepower per hour at partial loads can be represented by $0.95\ w + \frac{80}{B.H.P.}$ with an accuracy of about ± 4 percent (w = full load fuel consumption pounds per brake horsepower per hour).

The engine which showed a total fuel consumption at no load appreciably over 10 percent of the full load consumption used an independent injection air compressor. Hence engines running an appreciable part of the time at low power should be provided with attached auxiliaries at least from an economy point of view.

Statements of whether the fuel oil pump stroke was varied or what other methods were used to control engine speed at low powers would be of interest I believe.

F. L. DU BOSQUE, superintendent, floating equipment, Pennsylvania Railroad Company, New York: Since the inception of Captain Gatewood's idea, and following the completion of the designs of the engines referred to in this paper, very considerable strides have been made relating to the weight and cost of Diesel engines without impairing their efficiency. I listened with considerable interest to the statement made by the president of our society yesterday, that air cooled aeronautic engines were being built with a weight not exceeding 1½ pounds per horsepower. Notwithstanding the difference in the character of fuel and the service in which these engines are used, there is an enormous difference in the weight of these engines and the engines referred to in this paper, which average around 250 pounds per horsepower. This leads naturally to the thought that there must be some place within this great range of difference, that the principles of one design modified by the principles of the other, will bring the weight of the Diesel engine within the limits of other successful prime movers, and it is encouraging to know that Diesel engine manufacturers have recently become impressed with this idea, accomplished, as apparently it must be, by adapting piston speeds heretofore considered beyond the range of good practice.

Experiments economically are usually made with small size units. Engines on the Diesel principle have recently been produced of 150 horsepower at a weight of 26 pounds per horsepower. Another manufacturer of a small size unit informed me a few days ago that he had successfully operated an engine at 1,600 feet piston speed for a considerable time, and that the engine ran smoothly until it approached a piston speed slightly above 2,000 feet per minute. Manufacturers of locomotives of the so-called drill engine type have ordered, or are about to order, engines of 500 horsepower having a piston speed of 1,400

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feet per minute. To make such engines suitable for steamships, the rotating speeds must be transformed into a suitable propeller speed, and at this time both the gear and the electric drive make this possible, and no doubt the fertile American mind will develop other successful and efficient means.

J. H. KING, engineer, marine department, The Babcock and Wilcox Company, New York: The thermal efficiencies and fuel consumption of the engines referred to in this paper would indicate that the Shipping Board will have some very efficient engines in its fleet. It is interesting to note, however, that none of these engines is notable for economy in the use of lubricating oil. The cost of this oil at about 55 cents a gallon cannot be overlooked. It is also interesting to note that all of these engines used a very good grade of fuel oil. One often hears statements that Diesel engines can use ordinary bunker fuel, but I have yet to find a motorship operator that does so. On the other hand several shipowners and one large shipyard have told me that they were unable to obtain from Diesel engine manufacturers any guarantee of performance with ordinary bunker fuel. Inasmuch as Diesel oil costs about 40 percent more than bunker oil, this naturally offsets quite a bit of the low fuel consumption.

Captain Gatewood has given us the weights of this machinery:

The engines installed in the *Tampa* weigh 740,443 pounds
The engines installed in the *City of Rayville* weigh 850,000 pounds
The engines installed in the *West Cussetta* weigh 966,270 pounds

Just think of it! 255 to 358 pounds per brake horsepower. The earning capacity of a ship is certainly not increased by carrying around all this weight.

I am sorry that Captain Gatewood has not given in his paper some very important data that would have been very convenient for reference, namely, the tremendous cost of this Shipping Board conversion program. As the Captain gave this information to this society last year, I venture, for the sake of convenient relation to his admirable trial records, to quote from the 1926 *Transactions* of this society as follows:

"I began with costs and I would like to end with costs, because I don't think it can be stressed enough. I have already said before the Mechanical Engineers and every place I could get it across, that the cost of the Diesel engine in this country is doing more to hurt the art and the application of the Diesel for power than anything that I know of. Its cost, from a marine point of view, is perfectly terrific. The *Tampa* job cost $740,000, or thereabouts, and that is the cheapest job we are going to get in the Shipping Board. The installation cost less in that case than in any other thus far, and the engine cost less and everything else on the ship is about the same, so that is the cheapest. It doesn't hold water from an economical point of view, primarily because the cost of the Diesel itself and the Diesel auxiliaries is so terrifically high.

"The Diesel engine for marine purposes today, for cargo purposes, is not, in my judgment, practical at all, and nobody but the United States Government is rich enough to pay for it."

I might add to Captain Gatewood's remarks, that while the *Tampa* cost $740,000 as above noted, the *West Cussetta* cost $811,570, the *City of Rayville* cost $819,600 and the *Seminole* cost $865,787.

It is greatly to be regretted that the Shipping Board does not pay more attention to the opinions of its experts, so that, in view of the statement just quoted, it is amazing to find that the Shipping Board has undertaken to convert the cargo steamships *Courageous, Defiance* and *Triumph* into Diesel electric motorships, at a cost of about $1,300,000 each. It is true that this sum includes the cost of altering the ship as well as the cost of the machinery. But, think of the tremendous amount of money being expended on this experiment!

The Shipping Board has made a fine contribution to our engineering knowledge by having made some actual installations, but, after the first lot had shown, in every case, such tremendous costs, why continue to waste the money on further tests? If there is anything of value in the Diesel engine, the American merchant marine certainly should be in position to take advantage of it, but why should the Shipping Board continue to subsidize the Diesel engine industry—for that is what it amounts to? I believe that the shipyards have contributed to this subsidy also, by doing work at a loss. But, if the Shipping Board can do any subsidizing, it would seem only in accordance with common sense to exert their efforts along lines that are more economical and commercially practicable.

It seems to me that this matter of cost is paramount. What does it matter if we have even a theoretically perfect engine, provided the cost of the equipment is so tremendous that the fixed charges on this investment render it impossible to make a profit on the operation of our ships?

We all want to see our flag on the seas. We want a merchant marine, as well as a navy, second to none. But we cannot have a merchant marine until we can operate ships privately at a profit and there certainly can be no possible profit when the investment is so tremendous that the fixed charges alone absolutely preclude any possible advantage from the type of machinery used.

It is a little early to expect any real data on operating costs of the ships in the conversion program. But I think that this society would be very grateful to Captain Gatewood if he would supplement this valuable paper by giving us another, next year, which would include data on operating costs of fuel and lubricating oil, as well as the cost of the crews even with the fewer men in the crew. Naturally, maintenance costs should be very low this first year, but data on cost of upkeep and repairs, as well as losses due to the time required to make repairs, would be very valuable. There are very few data available on this important item of repairs, although a shipyard has advertised in the marine papers that they have created a complete unit in their organization exclusively for Diesel repairs, where the same jobs are done over and over again. This would seem to indicate that repairs are quite numerous but a perusal of magazines devoted to the Diesel engine throws very little light on the cost of these repairs.

ELMER A. SPERRY: The first Burmeister and Wain Diesel engine weighed, dry, 450 pounds per horsepower. Today this figure is down to 250 pounds, so there is hope for development.

CAPTAIN R. D. GATEWOOD stated that he was not responsible for the Shipping Board Dieselization program; the credit belongs to Admiral Benson and Angelo Conti, who advised very soundly, well and enthusiastically regarding it. He hoped to present a paper next year giving the results of the first year's performance of the converted motorships. Analyses of the exhaust gases may be given next year or as an addendum to the present paper.

The cost of Diesels manufactured in the United States, he stated, is terrific and will react unfavorably on the industry unless the design and cost of workmanship are improved. The weight of the engines, he held, is immaterial in the case of cargo ships except as a function of cost. If reduced weight will reduce the cost without sacrificing reliability, let's have it. The lubricating oil consumption was high, he admitted, but in the tests of new engines it would be foolish to take chances and the actual consumption in service will probably be reduced 50 percent. For the same reason it was advisable to use a high grade of Diesel fuel oil in these new engines at first; if bunker oil had been specified, it would have given a black eye to the industry at the start.

The Shipping Board Dieselization program, comprising 10 motorships in service, 2 more to be installed and 8 to be built out of a fleet of 285 ships in 27 overseas routes, he said, not only created Diesel vessels for commercial practice but also aided the Diesel engine industry and the Army and Navy. The crews are the same as on steamships.

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Diesel Engines for the Navy

By Edward C. Magdeburger

This paper reviews the existing oil engine installations in various navies of the world and gives a chart for a quick estimate of the principal dimensions of an oil engine. A discussion of the requirements of a high speed naval propelling plant develops the conclusion that for this purpose an oil engine is not suitable for direct coupling to propellers. As a solution of this problem it is suggested that 2 or 4 high speed engines might be connected to a suitable reduction gear through hydraulic couplings or that a similar arrangement might be used for driving generators for a Diesel electric plant. The paper also outlines 4 previous proposals made for using oil engines in a naval propelling plant. The installation of oil engines for an auxiliary plant of a naval vessel is reviewed and the requirements analyzed.

An abstract of this paper will be published in an early issue.

DISCUSSION

B. V. E. NORDBERG: Mr. Magdeburger presents many interesting examples of modern Diesel engine development which prompts me to enlarge upon reasons as to why the double acting, two cycle engine is the answer for large powers. As regards the requirements of the Navy, large powers are of prime importance and some of the limitations which Mr. Magdeburger's paper brings out force such units to be rather high speed. There is no doubt about high speeds coming into more general use, which of itself adds to the capacity of a unit more safely than a number of means being tried today. It is an open question as to what constitutes safe high position speeds and some of my early experiences have led me to adopt piston speeds over 950 feet for heavy duty work, many years ago when 750 feet per minute was considered very high. Today speeds of 1,200 to 1,400 feet per minute are used, so that 1,200 feet per minute could be considered safe and feasible.

High rotative speeds are not conducive to economy of an engine for they result in high fuel consumption and always lead to more or less difficulty. A reasonable rotative speed is always such as does not increase the fuel consumption per indicated horsepower beyond 0.33 pound per brake horsepower hour. When it exceeds this, difficulty with the parts in contact with the combustion gases becomes abnormal.

The proper relation of bore and stroke is also difficult to fix a limit for and this will vary with the type of scavenging arrangement. (I speak of two cycle engines only). This relation may be as much as twice or twice and a half of the bore for slow speed engines and about 1½ for medium speed units. However, the length of the stroke is dependent upon the height available in the hull, but where there are no limitations, the greater piston speed is to be preferred rather than the high rotative speed.

Bearing in mind the consideration only of large powers we can see a conservative piston speed of 1,200 feet and a reasonable rotative speed of 150 revolutions per minute which would then determine a stroke of 48 inches. A smaller cylinder than 38 or 40 inches need not be considered, and such diameter and stroke length should make it possible to use almost any design of scavenging arrangement successfully. Cylinders of this diameter have already been produced and experience enough is behind us to foretell what characteristics of design must be adopted. So far in this consideration we have not trodden upon any new ground and are reasonably sure of a successful result.

The mean effective pressure to adopt has been a source of considerable discussion, as a safe mean effective pressure is still being sought for. It must be sufficiently high to make an inexpensive and light weight engine and not high enough to shock our sense of the conservative. We are satisfied with an engine of 65 M.E.P. if it still has sufficient load capacity. Special means are being adopted today to increase the M.E.P., such as supercharging, exhaust throttling, and the like. While I have had a great deal to do with supercharging for increasing the rating of engines, it is not possible for me to set down a figure and definitely say that it must not be over-stepped for a continuous load condition. In a recent unit that I have designed we were able to attain a little over 100 M.E.P. without the slightest indication of a smoky exhaust and the only reason for limiting the output of the engine was that the fuel pump capacity was not great enough.

In this field also there is much research being done and much more to be found out. Two motorships have already been equipped with supercharging devices and both these ships, the *Preusen* and *Hansestadt Danzig* are operating with considerable promise of success. To a naval ship conversion, such as Mr. Magdeburger suggests, there is an additional possibility here, at least, for increasing the power output in case of emergency.

However, we will be satisfied for the present with 65 M.E.P. We can produce a unit of 39 by 48 inches stroke with 150 revolutions per minute. It is single acting, two cycle type, having a capacity of 1,420 brake horsepower per cylinder or a 6 cylinder unit would be capable of developing 8,500 brake horsepower. Such an engine would weigh in the neighborhood of 160 to 170 pounds per brake horsepower and be capable of heavy duty work with a minimum of difficulty.

If this unit were made double acting, it could be made to develop 2,500 brake horsepower per cylinder, and in a 6 cylinder unit it would be 15,000 brake horsepower, which would be the same as the engine recently built by Blohm & Voss, where 9 cylinders were used for this particular power. I have proposed such a unit on several occasions and have developed the design far enough to indicate that no abnormal difficulties would result nor unusual features of design would be necessary.

A single cylinder, double acting engine has now been built and is under trial at the Works of the Fiat Company in Turin, Italy, which has developed an output of 2,000 brake horsepower running at 150 revolutions per minute. The leading dimensions are the following:

Cylinder bore	33½ inches
Stroke	39⅜ inches
R.P.M.	150
Mean effective pressure	78.4
Mechanical efficiency	75 percent
Piston speed in feet per minute	984
Approximate height of engine	29 feet 6 inches
Approximate width	11 feet 6 inches

This engine has undergone a considerable amount of testing and it is reported to have a fuel consumption as low as 0.42 pound per brake horsepower hour. The experimental engine has been built almost entirely from cast steel due to the fact that Fiat is equipped with an excellent steel foundry, capable of turning out such large castings more efficiently and economically than their grey iron foundry could cast the parts of cast iron. This particular unit is of the port scavenging type, having a scavenging air control valve located ahead of the scavenging port and operating by a cam. The results obtained from this engine so far are very promising and, at the speed which this engine will run, it indicates no unusual disturbances.

There is still a great deal of research to be done in the matter of large sized, double acting engines. Such a unit as I have described above as developing 2,500 horsepower per cylinder is still very much in the realm of the conservative and there is no new ground being traveled over nor any-

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thing that cannot be designed based upon actual experience. However, larger sizes should be experimented with as undoubtedly the Navy will want the question answered some day as to whether larger sizes can be built and exactly how large a unit will operate satisfactorily and successfully. There is no doubt but what it could very readily use a unit from 3,000 to 4,000 horsepower per cylinder. Research leading up to such a size should be encouraged by it.

E. NIBBS, chief engineer, Electric Boat Company: It is stated on page 8 as primary reasons that large submarines use indirect drive to obtain more economical fuel consumption and more reasonable wear. I believe these to be secondary, the primary being the necessity of obtaining the power required to give the surface speed, having in mind the limitation of the engines at present used, which prevent full advantage being taken of the total height available in the larger submarines combined with revolutions, electric motors for submerged work, as well as harbor requirements. I thoroughly agree with the conclusion, page 15, that for maximum outputs for minimum weight and space, the only solution is the high speed, double acting engine.

JAMES L. BATES, Bureau of Construction and Repair, Navy Department, Washington, D. C.: Mr. Magdeburger has stated on page 11, that the Diesel engine can now be designed and built to meet any naval requirement. From the standpoint of the naval architect, this assertion appears optimistic for reasons which are outlined below.

The fuel economy of the Diesel engine is of but secondary importance in the design of all ships covered by the provisions of the so-called "Washington Treaty." This is because "standard displacement," the measuring stick for the modern fighting vessel, does not include fuel. It results that a reduction in fuel consumption affects only the tank capacity of the ship, ignoring entirely the weight of the oil actually in the tanks.

The total horsepower now obtainable in a Diesel machinery installation is probably not greatly in excess of 40,000. This might be sufficient for a battleship of moderate speed but would probably be inadequate for the modern battle cruiser, light cruiser or airplane carrier.

Finding the weight necessary for the satisfactory installation of all the apparatus essential to the fighting efficiency of the modern war vessel is already a difficult problem. It is practically impossible to secure substantial improvement in one feature without corresponding sacrifices in one or more of the other features of a well designed ship. Because of this, the Diesel engine can hardly be considered seriously for surface fighting ships until it approaches the weight standards of present steam installations more nearly than is now the case. In order to emphasize this point, the following comparison of the shaft horsepowers per ton of engineering weight characteristic of several types of surface fighting ships, has been prepared.

	Battleship	Battle Cruiser	Light Cruiser	Destroyer
Type of machinery	Steam turbine with mechanical or electrical reduction gearing.		Steam turbine with mechanical gearing.	
Shaft horsepower	30,000 to 50,000	80,000 to 150,000	40,000 to 120,000	30,000 to 50,000
Shaft horsepower per ton of engineering weight	17 to 21	22 to 27	40 to 50	55 to 65

The horsepowers per ton of engineering weights given in the above table cover the entire engineering department, including main propelling units and their auxiliaries; ship's power, lighting and heating plant and all miscellaneous engineering items, such as piping, gratings, miscellaneous tanks, water in machinery, etc. The main propelling units, including boilers, turbines and reduction gears may be taken as from about 35 to 45 percent of the weight of the entire engineering installation in the cases of battleships and destroyers, respectively.

The writer has been unable to secure weight data of similar value to that given above for Diesel installations because the information usually published applies only to the bare engine. Based partly upon figures previously published by Mr. Magdeburger, in the *Journal of the American Society of Naval Engineers*, the shaft horsepower per ton bare engine weight may possibly reach 40 in installations of such as 40,000 shaft horsepower. Assuming such an installation to be suitable in other respects for a battleship, it might be possible to secure a Diesel installation on about 15 horsepower per ton of engineering weight. In a battleship having a standard displacement of 35,000 tons, a weight of about 2,800 tons might reasonably be allotted to engineering. This would provide for 42,000 shaft horsepower in a Diesel installation at 15 horsepower per ton engineering weight and for 53,000 in steam at 19 shaft horsepower per ton engineering weight. The difference in speed due to this difference in power is about 1⅛ knots in favor of steam.

The tabulation below shows what may be considered fairly representative of the percentages of the standard displacement allotted to the principal weight divisions in several types of surface fighting ships.

	Battleship	Battle Cruiser	Light Cruiser	Destroyers
Hull and fittings	37	37	51	47
Protection	33	28	10	0
Engineering	8	18	23	42
Armament and ammunition	19	13	9	5
Equipment, outfit, stores and water	3	4	7	6

Consideration of this and the preceding table brings out the fact that the difficulties already referred to are more serious in the cases of the other types of ship than in that of the battleship. This is because high speed is emphasized.

The foregoing comments have been submitted to indicate the developments in Diesel machinery, viz., increase in available power per unit and in horsepower per ton of engineering weight, which would assist the naval architect in the design of surface fighting ships. It would appear that these improvements might be expected through the development of the light high speed types driving through reduction gearing rather than through the larger heavier types driving direct.

In any case it is to be hoped that the experimental work necessary to such development may be undertaken by the Navy Department in the near future. It is believed that this is of particular importance to the department because of the advantages from the standpoints of smoke disposal and underwater subdivision which Diesel machinery appears to offer. It is also felt that such a development, while perhaps of ultimate advantage to commercial interests, could hardly be undertaken by them because of the great expense involved.

COMMANDER JAMES M. IRISH, U. S. N.: The review of the Diesel engine situation in the Navy demonstrates that naval engineers in practically all navies have yet to be convinced of the advantage of adopting Diesel engines over present existing types. This conservatism is based on the well recognized considerations which govern the selection of any machinery installation in warships—reliability, weight, space, simplicity, economy. The final selection must be a compromise depending on the type of ship under consideration, and a new type of installation must prove its case before being adopted. There is no question in the high speed destroyer or cruiser type and the author has therefore centered his argument on (a) the auxiliary type and (b) the battleship.

From a point of view of propulsion, the slow speed reciprocating engine was so well suited to the most efficient propeller that it was favored long after the turbine had demonstrated its greater efficiency. Somewhat similar conditions exist in the present status of the Diesel engine and

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until thoroughly demonstrated naval engineers will continue to hesitate before widely adopting it for major installations. The electric drive has solved this problem very satisfactorily and a test case for the author's proposed installation of Diesel drive is essential.

The parallel between the *Jupiter* as a test case for electric drive and the *Maumee* for the Diesel engine is excellent. Sane and logical conclusions could be drawn and many engineers who are doubtful of the Diesel engine would, if the *Maumee* made good, become enthusiastic. In the writer's opinion the outlay of money would pay large dividends in experience and serve as a foundation to build on for future installations of the size necessary for major ships.

For the auxiliary plant the author has demonstrated that there is a large field for Diesel driven generators. But before this can be adopted, numerous related problems must be solved. Ships of the Navy must be self-supporting, and one of the greatest problems in this connection is that of fresh water supply. Water for boilers, and general ship use must be distilled on board in large quantities and steam is essential for numerous purposes in the galleys, for heating and in other minor ways in the upkeep of the ship. The gain in economy in the generators if Diesel driven is largely nullified if it is necessary to operate a boiler at a low and uneconomical rate to obtain this steam. It is not at all certain that all this can be obtained from exhaust heated boilers as stated in conclusion No. 3. It would mean a large, heavy installation, and weight and space again enter on these minor installations as well as on the main plant. The Diesel plant for auxiliary purposes undoubtedly has a place on board naval ships, but it is doubtful if it will entirely displace the steam driven units.

OTTO A. BANNER, manager oil engine department, The Falk Corporation, Milwaukee, Wis.: Mr. Magdeburger's investigation has led him to propose two designs for an oil engine driven naval vessel. The first consists of geared oil engines with hydraulic clutches, the second of a geared oil engine—electric drive, in which again hydraulic clutches are incorporated. The second drive is too complicated to be serously considered here.

Any marine propelling plant especially on a warship should be as simple as possible. For this reason alone, the hydraulic clutch should be avoided. This clutch requires a complete auxiliary installation of pumps, coolers, tanks, piping and a complicated control gear. When operating it entails a constant loss of from 4 to 5 percent of the power it transmits. If this loss shall be reduced to 3 or even 2 percent, the auxiliary installation becomes very large, costly and heavy.

The development of the geared oil engine with hydraulic clutches has come to a standstill after a few initial installations have been placed in operation.

The contrary can be said of the geared oil engine with mechanical connection between engines and pinions, a steadily increasing number has been and is being fitted with this type of engine.

In the face of repeated statements of all authorities that a twin geared oil engine must be a failure, the Falk Corporation which had previously built the gears for the first sea-going motorships with geared oil engines, the *Libby Maine* and the *James Timpson*, started building a quadruple, geared oil engine with mechanical coulpings having four engines acting on the two pinions of the gear unit, as early as 1920. This engine was in operation as early as fall 1922.

This engine was a bold departure from all existing precedents, it has furnished most valuable information and has been in remarkably successful continued operation for nearly 5 years now. It has demonstrated among other things that it can equally well be operated with four, three, two or one engine connected to the gear unit. Also that the early apprehensions concerning difficulties of common reversing, starting and controlling the engines were absolutely without foundation. Wear of gear teeth and bearings is negligible, there have been no charges for repairs or replacements of any part of the gear unit.

Added to the list of European motorships propelled by geared oil engines must be the American tanker *Herman Falk* which is operated by a twin geared oil engine built by the Falk Corporation. This ship has 10,250 tons deadweight capacity, the engine is a twin 8 cylinder of 2,600 brake horsepower rated capacity at 90 propeller revolutions. The cylinder diameter is 18 inches, stroke 22½ inches, engine speed 275 revolutions at rated load. The engine is of the single acting, four cycle trunk piston type.

Whereas Blohm & Voss use rigid couplings, the Falk Corporation fit their well known flexible couplings between engine crank shafts and pinions. It is obvious that the Falk method is superior to the Blohm & Voss method because it eliminates all crank shaft reactions from the pinions, permitting the use of light foundations.

When it comes to a study of the application of the mechanically connected geared oil engine to the propulsion of naval vessels the method of increasing the power of oil engines by supercharging should be considered. Remarkable results may be obtained by simply scavenging the compression space of our engines with low pressure air.

The power plant which I propose for a vessel of 36,000 shaft horsepower maximum would consist of four propellers each operated through single gear unit by four 6-cylinder oil engines. Two engines would be operated for all speeds up to cruising speed. For speed increases, over short periods, cut in supercharges; over long periods, cut in one or both of the reserve engines. Operate without or with increasing supercharging pressure to obtain desired speed up to maximum. This plant is the lightest and the least complicated, it reduces transmission losses to the possible minimum, and gives good economy.

Mr. Magdeburger raises the question of the limiting size of geared oil engines. This is solely determined by the size of the oil engines, not of the gear unit, so long as sufficient distance between centers of pinions can be permitted. There is no reason why a gear unit of 10-foot center distance of pinions and, for instance, 300 revolutions of the engines, 350 revolutions of the propeller, could not be built to operate perfectly satisfactorily at 30,000 horsepower per shaft.

Concluding, I may mention that the engines coupled to the gear unit may be two pairs of different sizes. Such an arrangement may become desirable if cruising at low speed over long runs is necessary, when the cruising engines would be selected smaller than the reserve engines.

EDWARD B. POLLISTER, general manager, and Max Rotter, vice president, in charge of engineering, Busch-Sulzer Bros.-Diesel Engine Company, St. Louis, Mo.: The possibilities in the application of Diesel engines to marine service, even on the broad lines indicated by Mr. Magdeburger, may be tabulated as follows:

(1) Steam direct propulsion, with Diesel auxiliaries;
(2) Steam indirect propulsion, with Diesel auxiliaries;
(3) Diesel direct propulsion, with steam auxiliaries;
(4) Diesel direct propulsion, with Diesel auxiliaries;
(5) Diesel indirect propulsion—(a) by gears
(b) by hydraulic transmission
(c) by gear hydraulics
(d) by electric conversions
(e) by gear-electric
(f) by hydraulic-electric
(g) by gear-hydraulic-electric

In each case with steam or Diesel auxiliaries.

Excepting the case of large fleet submarine, space and weight limitations (not to mention the desirability of max-

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imum simplicity) will generally restrict the power plant to a pair of Diesels, normally coupled directly to the propeller shafts. The possible advantages of an indirect drive are very slight or entirely absent, because directly-propelling submarine engines usually operate very nearly at the highest speed practicable for engines of their power capacities. It would be interesting to know to what extent, if at all, the charging of batteries or the running of only one engine and driving the other propeller by electric current from the generator of this engine, during the periods of low-speed cruising, favors this class of service, as compared with ordinary marine service.

For cruisers and capital ships Mr. Magdeburger clearly favors indirect propulsion, as best suited to the special strategical requirements which distinguish such ships from naval auxiliaries and commercial vessels; but it appears to the writers that, at this date, experiences are too limited (as applying to Diesel indirect propulsion) to warrant a broad general verdict. Such important considerations as maintenance costs, continuity of service, and reliability of maneuvering, are as important as comparative fuel consumptions and first costs; but are not yet as definitely demonstrable. These special considerations involve comparisons of wear and tear of directly-propelling engines at low speeds; as against indirectly-propelling engines at high speeds, plus their intermediate mechanisms. They are affected, also, by the relative ability to adapt their operation to and to withstand the sudden and severe loads caused by heavy seas; in which respect the directly-propelling engine appears to have advantages, certainly over the electric drive.

In Fig. 9 of Plate 5, has not Mr. Magdeburger overlooked allowances for losses in efficiency when less than the total number of engines are in operation, but the entire trains of gears and parts of the couplings continue to run? Would not due allowance for these give the drive efficiency curve a character more like that of the electric drive, as shown in Fig. 10 of Plate 6?

As applied to engines of large capacity and low rotative speeds, Mr. Magdeburger's general opinion concerning the advantages of double acting, 2 cycle engines is undoubtedly correct; but the writers take issue with him concerning the power capacity at which such advantages will begin to be manifest—especially when the simplicity, present state of development, and efficiency of the single acting engine are given weight—and suggest a study of the published figures relating to dimensions and weights of the 3,000 to 4,000 brake horsepower directly-propelling Diesels recently contracted for by the Shipping Board; as also the published records of the 30-day tests of the Diesels furnished to the Shipping Board for its previous conversion program. The art is young, relating to double-acting Diesels, and their dimensions, weights, efficiencies, and reliability will certainly be improved substantially; but at the present time it would seem that the step from single to double acting should be made at 5,000 or 6,000 brake horsepower, rather than 2,000.

For auxiliary service on naval ships, whether steam or Diesel propelled, the writers share Mr. Magdeburger's views, and cannot conceive any condition or consideration which would favor other than Diesel auxiliary engines. It appears strange, therefore, that the Navy has not done more in this direction.

R. HILDEBRAND; chief engineer, Diesel division, Fulton Iron Works Company, St. Louis, Mo.: While the gear drive may be the final solution for naval vessels and even for commercial vessels, because it permits the use of high speed Diesels, yet there seems to be another possible way of meeting the requirements of Diesel driven naval vessels, provided the room required permits the installation of the power plant which the writer has in mind. What the writer proposes is to couple the propeller shaft directly to an engine with small cylinders of sufficient capacity to deliver say one-half the Diesel horsepower required when the vessel operates at full speed. Such a small engine will probably go below the protective deck and it will operate economically while the vessel is cruising with reduced speed. At half speed, i.e., with approximately half the propeller speed, the engine will carry about a 50 percent load. At a 50 percent load, the efficiency of the engine will still be high. In order to increase the normal rating of the engine by 100 percent to meet full speed requirements of the vessel, the writer proposes to design the working cylinders so that they may be used either as Diesels or as steam engines or simultaneously as Diesel-steam engines.

When cruising, the engine will work as a pure Diesel and its indicator card will resemble that of Fig. 1 which

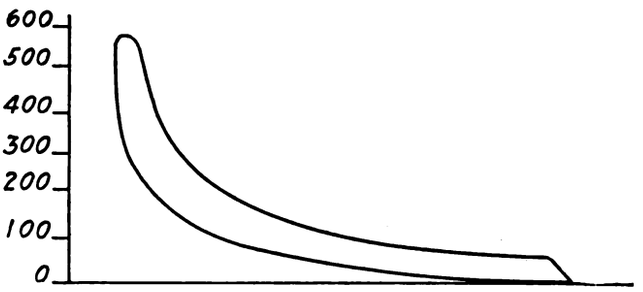

Fig. 1

shows a normal two stroke cycle card. When the maximum shaft horsepower is required, Diesel plus steam power will be used. When steam is used, in addition to Diesel power, the steam will be admitted into the cylinders after the combustion of fuel is just completed, and after the gases are expanded to the pressure which about equals the steam pressure. The indicator card, while using Diesel and

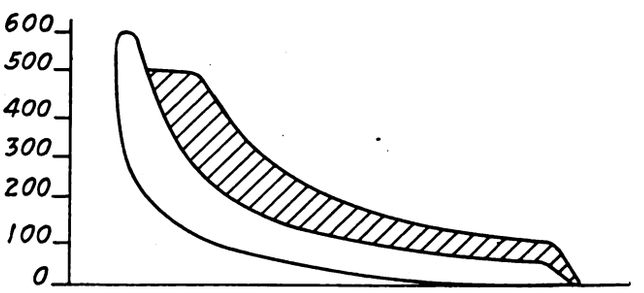

Fig. 2

steam power, will be similar to the one shown in Fig. 2. The cut-off chosen in Fig. 2 admits just so much steam that the auxiliary steam power (shaded area) increases the Diesel power by 100 percent.

Admission of the steam into the Diesel cylinder, and mixing it with the hot gases therein, will prevent dangerous overheating of the power cylinders, because the steam, even if superheated, will have a cooling effect on the hot combustion chambers. The higher the load, the more steam will be admitted, the more effective will be the internal cooling of the combustion chamber. Adding steam, however, will increase the heat carried away by the exhaust thereby reducing the thermal efficiency, although the steam consumption per steam-horsepower-hour is a very favorable one.

The proposed engine, being a Diesel-steam engine, resembles to a certain extent the Still engine. It is double

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acting, but it develops Diesel power (high efficiency) and steam power (high overload carrying capacity) on both sides of the piston. Thus, with the same cylinder volume as the Still engine it will have about twice the overload carrying capacity.

There may be a question in the reader's mind whether the steam mixed with the products of combustion will cause an undesirable chemical effect (corrosion) on the cylinder walls? There will be no chemical reaction because the highly superheated steam, while expanding together with the hot Diesel gases, will not condense to water. The sulphur dioxide (SO_2) and trioxide (SO_3), contained in the products of combustion, cannot change into sulphuric acid (H_2SO_4) unless liquid water is present, which, however, will not be the case in the proposed engine.

Stand-by boilers will be needed. Their capacity should be sufficient to carry the load above the Diesel rating. Since the working cylinders must be designed for 550 to 600 pounds initial pressure, it is highly advisable to use also

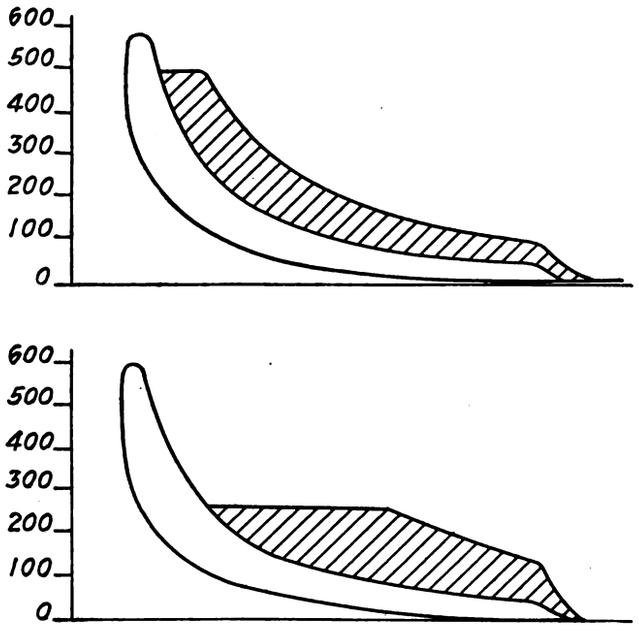

Fig. 3

a high boiler pressure, say at least 500 pounds gage. Fig. 3 will illustrate this. Both cards show an auxiliary power of just 100 percent, but the cut-off is much shorter and consequently the economy much greater with the auxiliary power medium of 500 pounds than with the low pressure shown. These stand-by boilers, if desired, may be kept under steam all the time by the heat contained in the exhaust of the Diesel. However, it will be more efficient to use this heat in a low pressure auxiliary boiler or in a scavenging air boiler, and to start the high pressure stand-by boilers whenever they are needed.

The working cylinders will be equipped with steam inlet valves at both piston sides. In case the engine is of the two stroke cycle, port scavenging type, it will not be difficult to accommodate the valves which will be operated by a reversing gear.

The engine may also be operated as a pure steam engine and it will then be possible to run it at very low speeds. This may be desirable during maneuvering and when navigating waters similar to the Panama Canal.

The jackets of the cylinders may be used as a low pressure boiler as in the Still engine. However, it is desirable that the steam generated, after being condensed, is pumped back into the cylinder jackets. Using condensed steam (distilled water) in the jackets, no scale will be deposited.

Modern Trend of the Diesel Engine

By Otis D. Treiber

This paper outlines briefly the factors which up to the present time have influenced Diesel engine design with respect to low weight per horsepower, high revolutions per minute and high mean effective pressure and shows that the modern trend is toward the lighter weight, higher speed machine, a number of which have proved very satisfactory in generating plants. A table is given showing a comparison of various well known engines in regard to brake horsepower, mean effective pressure, revolutions per minute, piston speed, weight per horspower and brake horsepower developed per 100 cubic inches of piston displacement. An analysis of the theoretical limits of mean effective pressure and thermal efficiency indicates that mean indicated pressures can be and have been obtained as high as 160 pounds per square inch. The use of modern materials, such as alloy steel castings, forgings and alluminum alloys permits tremendous reduction in the weight of an engine and stressing the various members at higher unit stress than is possible for cast iron. An analysis of bearing pressures shows that inertia and centrifugal forces contribute to reduced maximum bearing pressures as the speed of an engine is increased. The paper also contains data and drawings of a light weight 3,000 horsepower Diesel engine now under construction. An abstract of this paper will be published in an early issue.

DISCUSSION

E. C. MAGDEBURGER, Aide on Diesel engines, Navy Department: Mr. Treiber's paper is hardly true to its title and in my humble opinion does not reflect the "modern trend of the Diesel engine" as a whole, but is rather a justification of his own attempt to build an engine of "low weight per horsepower, high revolutions per minute and high mean effective pressure." This motive makes it rather dogmatic and full of statements which are at variance with facts as they are generally known to that part of the engineering fraternity that has reasons to be interested in the Diesel engine.

It would therefore be quite interesting to a large number of engineers, I believe, if the author would elucidate some of his statements, if possible, so as to permit us to follow his deductions with greater ease and await the fulfilment of his expectations with more confidence, for as yet the engine described is but an inanimate mass and cannot speak for itself in demonstration of the designer's ideas.

It is of interest to know, for instance, where steel piston rings were proven a success and who is actually using them. Likewise it is mentioned that "copper pistons have been used successfully." The question is whether this reported success brought them out beyond the laboratory walls. The author also mentions the fact that "magnesium alloys are now being tested for both piston and connecting rods," but are these experiments not confined to aviation engines of rather small cylinder dimensions and hence hardly applicable to a type of engine described later?

Details forming the basis of the assertion that "in a Diesel electric drive there is a weight saving over the direct drive of 40 percent where engines of 400 revolutions per minute are used with a propelling motor of 100 revolutions per minute" would be very desirable since it is at variance with a statement made by Mr. Thau in a paper presented before this society last year, who claimed that "the weight of Diesel electric drive is generally less than that of the single acting, direct connected Diesel drive of the same revolutions per minute and approximately the same as that of a double acting direct Diesel drive." In the recently awarded Shipping Board contract for converting three ships to Diesel

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electric drive only a very insignificant advantage in weight for this type of drive was claimed.

It is also quite difficult to agree with the author that "the problem of heat control of the metals adjacent to the combustion chamber is purely mechanical and has no limitations within the present knowledge of the art." Mechanical or otherwise, it is a very serious problem and the most potent limitation of any existing design of Diesel engine and particularly so in high speed submarine engines. This limitation is very much more important, in my opinion, than any possible lack of oxygen to support combustion, since cylinder heads crack long before the supply of oxygen in combustion air becomes exhausted, due to excessive temperature of the exhaust gases, caused by late combustion and inability of the gases to lower their temperature by proper expansion. Would that not explain, for instance, the fact that the Beardmore high speed engine (8.25-inch by 12-inch cylinder) developed its rating at the modest brake mean effective pressure of 81 pounds per square inch when running at 750 revolutions per minute and with piston speed of 1,500 feet per minute. This engine being the nearest to the one designed by the author, it would be of interest to know the reasons for the claimed superiority of the new engine, which is supposed to develop 110 pounds per square inch brake mean effective pressure when running at 700 revolutions per minute and having a piston speed of 1,866.6 feet per minute.

Just why "the single acting, trunk piston, four cycle type engine using solid injection offers the greatest possibility for lowest weight of reciprocating parts, which is the most important factor in limiting revolutions," was not explained by Mr. Treiber, although he recognizes that "the inertia of valve mechanism is an important factor." Such a statement can hardly be left unchallenged since there are at least three different two cycle engines of automotive type operating from 1,200 to 1,650 revolutions per minute and with piston speeds up to 1,750 feet per minute which are out of the experimental stage—Attendu, Junkers and Peugeot. Exception must also be taken to the statement that "attempts have been made to produce a commercially satisfactory high speed two cycle double acting engine, but the time element for scavenging is difficult to master and as yet it has not successfully been done to my knowledge." The failure of this unnamed attempt, that evidently never received much publicity, can hardly be attributed to scavenging as the existence of the above mentioned successful engines would indicate.

Experience is the common heritage of mankind but progress is made by but few. Let us hope that the forthcoming tests of the engine designed by the author may prove it to be a step in the right direction.

H. SCHRECK: I wish to call attention to the indicator cards on Plate 8. These results are remarkable, because an indicated pressure of 150 and 160 pounds per square inch, with a clean exhaust and without supercharging is a record accomplishment. I understand these cards were taken on the Bessemer Diesel engines, which are the accomplishment of Mr. Treiber; they are the product of his personal work and he deserves high recognition for such results.

Such record, therefore, holds great hope for the success of the present development in the light weight 3,000 horsepower engines running at 700 revolutions per minute which Mr. Treiber is now building. It is a development which is wanted in the Diesel engine line, that is, high speed, light weight, and yet an absolutely reliable engine. How far we can go in this respect with allowable stresses under consideration of fatigue of material on commercial engines must be tested out.

On the thermodynamic calculation of this paper, I cannot quite agree with Mr. Treiber. Turning to Plate 1, I cannot see why the efficiency curve should have such a pronounced hump when this curve is a function of the indicated pressure shown by the lower curve on the same plate. I calculated the case presented in this paper by laying out the diagrams on the well known Stodola entropy chart. There is a considerable difference between the figures arrived at by Mr. Treiber and those of my calculation. The curves of indicated pressure, maximum pressure, and temperature on Plates 1 to 6 are affected, more or less, by the calculation. If my curve of efficiency is correct, the closer we approach the Otto cycle (100 percent constant volume combustion) the more efficient is our engine.

JOHN F. FOX, Navy Yard, New York: The mean effective pressures advocated are higher than usually considered permissible, but as the production of a light weight engine is as much dependent upon the highest possible mean effective pressures and piston speeds as upon light weight of parts as such, every effort must be made to so proportion the design that these high piston speeds and mean effective pressures, together with the temperatures which they entail, can be safely carried. Any reduction in mean effective pressure below the maximum that can be carried with efficient combustion is an admission on the part of the designer that his design is in some way defective in the matter of cooling or materials used.

The production of a really high speed engine is primarily a matter of light moving parts, rigidity of structure, and efficient lubrication. Heavy moving parts, apart from their effect in increasing bearing loads at high speed, are disastrous when the problem of vibrations of various kinds is taken into account. Particularly, in the matter of torsional vibration is this the case, as many of the torsional periods that give trouble arise from the harmonic components of the inertia forces set up by the reciprocating parts. If the reciprocating parts are relatively heavy, vibrations which might otherwise not build up to a dangerous amplitude may become sufficiently troublesome to make necessary the avoidance of operation at the speed effected. At the very least the range of the torsional periods will be increased. This is, of course, particularly the case where the engine must run at varying speeds as in an engine propelling a ship. A safe rule to follow is to use the lightest possible reciprocating and rotating parts and the stiffest possible shafting.

HARTE COOKE, engineer, McIntosh and Seymour Corporation, Auburn, N. Y.: On page 9, it is stated that "the problem of heat control of the metals adjacent to the combustion chamber is purely mechanical, and has no limitations within the present knowledge of the art." In general, it is the ability of these materials surrounding the combustion chamber to take care of the heat which limits the output of the Diesel engine.

In regard to the statement on page 10, that bearing destruction comes from maximum pressures—this might be true if the pressures were so high as to crush the babbitt, but examination of the crank shafts in Diesel engines which have run for long periods shows that inertia forces have a very considerable effect on the wear of the shaft.

In regard to the mean effective pressures which can be satisfactorily used over long periods, experience has shown that this is determined more by the effect of the heat on the metal surrounding the combustion space than by the amount of oil that can be burned. This is shown on page 7 of paper No. 10, which gives the analysis of the exhaust gases from a large marine engine under test, showing that the exhaust gases contain 15.4 percent of oxygen. This excess oxygen shows that a considerably higher mean effective pressure could have been developed, which would have given an increase in the output of the engine, without any increase in the weight or cost. The fact that a higher mean effective is not used shows that the limitations are in other directions than burning more oil in the cylinders.

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Vibration and Engine Balance in Diesel Ships

By Professor Frank M. Lewis

An abstract of this paper will be published in an early issue.

The Annual Banquet

AT the annual banquet of the Society of Naval Architects and Marine Engineers held at the Waldorf Astoria Hotel, New York, Friday evening, November 11, United States Senator Royal S. Copeland in discussing the future of the American Merchant Marine declared that "Americans must decide what shall be the future of American shipping. Without a change of program no American ship will be left in overseas trade.

"There are three ways of dealing with this problem. We may provide naval subventions, using a part of the naval appropriation for the upkeep or assistance of certain merchant vessels which may be necessary as auxiliaries of the navy.

"The second way is by favorable mail contracts, so that the income of our ships would be pieced out to the extent of making it possible for them to operate. In all probability this is the least offensive way of providing the assistance our merchant marine must have if it is to live. As a matter of fact, this aid could be given at once and without added expense to the government, if there were vessels of suitable speed on certain lines now in operation.

"The third way of assisting the development of an American merchant marine is by direct appropriation.

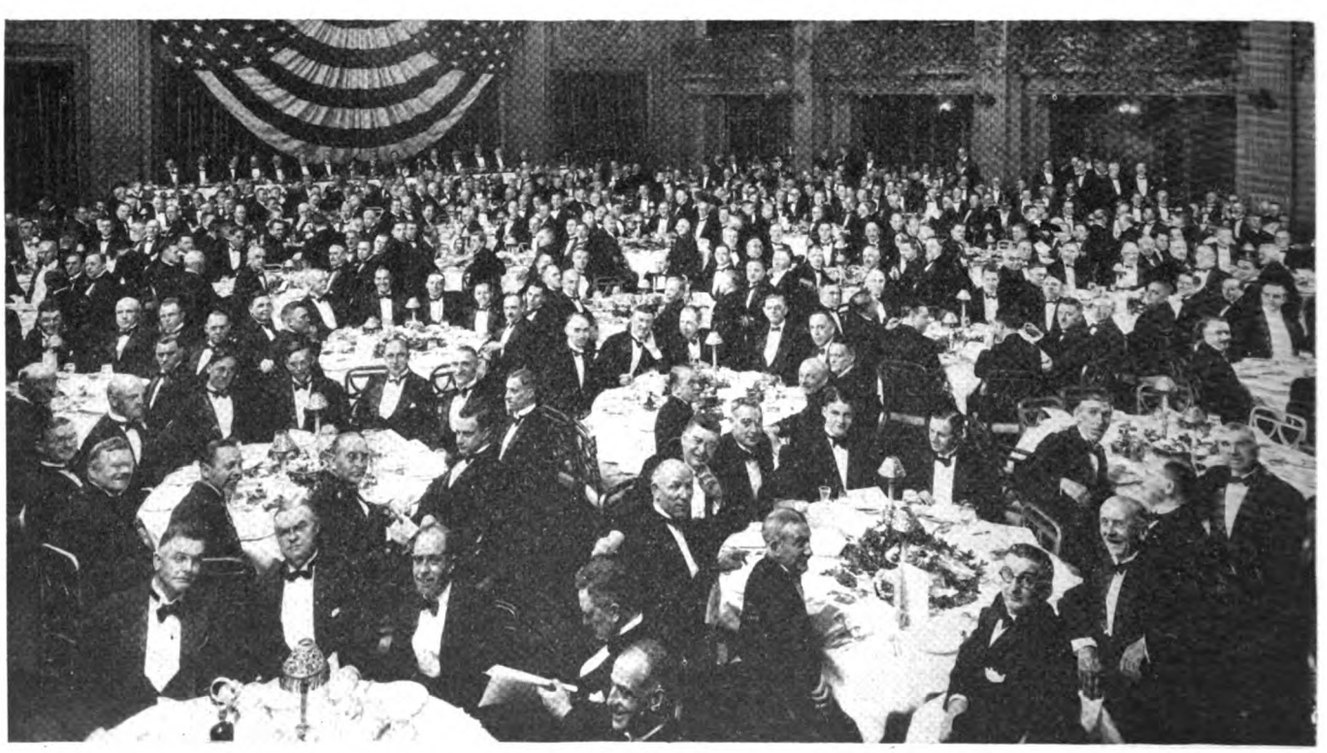
"Beyond these three possible solutions is a fourth, and that is continued government ownership and operation, or government ownership with private operation. This last suggestion would involve the government making up any deficits which might result from the operation of the ships.

"The United States must have a merchant marine for commerce and for the national defense. This is a national not a sectional question. If the Government is to continue in the shipping business, it should speedily begin the construction of at least two swift ocean-going vessels of the type of the *Leviathan*. This must be done to meet the competition of foreign vessels. As auxiliaries of the Navy such ships are as necessary as naval cruisers and battleships. Their cost may well be charged to the cost of national defense, for they are an important part of the national insurance.

"If the Government is to abandon the building and operating of ocean-going vessels and the building and operating of such vessels is to be turned over to private capital and private corporations and private shipyards, some plan must be put into operation soon whereby the builders and operators may be properly aided. Without such aid, an adequate merchant marine is out of the question. The American people must decide which course to pursue, if they are not to witness the disappearance of large and swift American vessels flying the American flag."

In the absence of T. V. O'Connor, chairman of the United States Shipping Board, who was to speak to the Society, Commissioner P. S. Teller of the Board read the paper which Mr. O'Connor had prepared on "The Past, Present and Future of the American Merchant Marine." Chairman O'Connor concluded by saying that we who are in touch with shipping sentiment throughout the land have for some time past been aware of a growing insistence that the people of the United States no longer adopt half-way measures in dealing with their foreign shipping competitors; that we no longer suffer the handicap of makeshift equipment; that we lose no further time in meeting the world's demand for speedy ocean transportation. We must have a modern fleet—*and keep it modern*. In no other way can we hope to maintain a permanent place among the great maritime nations of the world.

The last of the scheduled speakers was Chester Leasure, associate editor of the *Nation's Business*, who made a strong plea for private operation of American shipping.



Annual banquet of the Society of Naval Architects and Marine Engineers, held at the Waldorf Astoria Hotel, New York on November 11

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Questions and Answers for Operating Engineers

Practical information for marine engineers on the operation and maintenance of boilers, engines and auxiliaries

This department is maintained to help those who desire practical information regarding engine room problems or who are preparing to take examinations for a marine engineer's license. Readers are urged to send in questions. Inquiries bearing the name and address of the writer will be answered promptly by mail. If the question is of general interest the answer will also be published in an early issue of the magazine, although the identity of the writer will not be disclosed in doing so. Anonymous communications will not be considered.

Chief Causes of Turbine Breakdown

Q.—What would you consider as the chief causes of breakdown in a turbine?

A.—Stripping of dummy rings and stripping of blades caused by main bearings wearing and causing rotor to drop due to lack of proper lubrication. Insufficient clearance between the rotor blades and the casing or casing blades and rotor when heated up. Sudden presence of a body of water carried over with the steam.

Clearance in Parsons Turbine

Q.—In a Parsons steam turbine how much clearance is allowed between the moving and the stationary parts?

A.—The tips of the revolving blades just clear the walls of the cylinder and the tips of the stationary blades just clear the surface of the rotor.

Shaft Glands

Q.—What provision is made to prevent leakage of steam or air, where the shaft passes out to the high and low pressure ends of the turbine cylinder or casing?

A.—By means of glands that are made practically frictionless by steam or water packing without metallic contact.

Boiler Heating Surface

Q.—What is called the heating surface of a boiler and about how many square feet of heating surface are usually allowed per horsepower?

A.—All the surfaces that come in contact with fire or hot gases on one side and are covered with water on the other side. About 9 to 16 square feet all depending upon the type of boiler.

Broken Crank Shaft

Q.—In a modern triple expansion engine, if the low pressure crank shaft broke, how would you bring the ship to home port?

A.—Replace the broken shaft with a spare crank shaft or if there was no spare transfer the high pressure crank shaft to the low pressure, reduce the steam pressure and revolutions and run the engine compound.

Fire Fighting Equipment

Q.—What fire apparatus is required by law on board passenger steamers?

A.—Automatic fire alarm system, steam fire pumps and hand pumps, portable chemical fire extinguishers, fire hose, buckets *filled* with water, axes, etc. Steam smothering pipes to all cargo holds and bunkers.

Compound Non-Condensing vs. Single Engine

Q.—What would be the advantage of a compound engine running non-condensing over a single engine of the same power?

A.—The compound engine would be more economical due to a greater expansion of the steam.

Metallic vs. Soft Packing

Q.—What is the advantage of metallic packing compared with soft packing?

A.—Metallic packing will stand higher temperatures and pressures while soft packing has a tendency to burn and harden and often scores the rods.

Double Ported Slide Valves

Q.—Why are double ported slide valves sometimes used and on what cylinders?

A.—To reduce the travel of the valve by giving double admission at each end, hence the travel is shortened one-half. Double ported valves are used on the low pressure cylinder.

Fittings on Steam Engine Cylinders

Q.—What are the usual fittings generally found on steam engine cylinders?

A.—Relief valves, drain valves or cocks, indicator cocks, steam gage cock, stuffing box and gland.

Boiler Explosions

Q.—State a number of reasons for boiler explosions.

A.—The causes of boiler explosions are very numerous but the principal ones are over pressure, defects in design, workmanship or construction, carelessness or neglect in treatment, or ignorance on the part of the men in charge, corrosion, wear and tear, overheating from a shortness of water, safety valve improperly set or sticking, defective mountings, general deterioration of different parts of shell, tube sheets or furnaces.

Working Parts of Engine

Q.—Name the different parts of an engine through which the pressure of the steam is transmitted from the piston to the screw propeller.

A.—The pressure is applied through the piston, piston rod, crosshead, connecting rod, crank pin, crank shaft, coupling bolts, line shaft and tail shaft to the propeller.

How to Determine Wear on Turbine Bearing

Q.—How can you tell if a main bearing on a turbine has worn down?

A.—If a main bearing has worn it means the shaft is down and this condition can be found by the use of a bridge gage. This bridge piece is secured to the lower half casing just outside the gland, the pin being adjusted to a known clearance from the top of the shaft so that by applying this arrangement at intervals and a record kept, any drop of the rotor shaft can be found by using a feeler gage between the flat end of the pin on the bridge gage and the top of the shaft.

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Questions and Answers Relating to Naval Architecture and Marine Engineering

Conducted by James L. Bates, Naval Architect, and W. B. Newton, Marine Engineer

This department is maintained for the purpose of answering all questions relating to ships and their machinery. All inquiries should bear the name and address of the writer. Anonymous communications will not be considered. The identity of the writer, however, will not be disclosed unless the editor is given permission to do so.

Trial Loading for Cargo Vessels

Q.—Please discuss the trial loading for cargo carrying vessels.

A.—The purpose of conducting trials for any vessel is to ascertain, as accurately as may be, the machinery performance and the speeds which may be reasonably expected of the vessel when in service. Accordingly, the ship should be loaded to a draft closely corresponding to that to be anticipated in service. A cargo vessel may be able to load to her Plimsoll mark on both her outgoing and incoming voyage, or it may be practicable to carry a full cargo in but one direction and make the other trip in ballast. It results that, if practicable, trials should be carried out at drafts corresponding to both conditions. This may prove impracticable for the case of a general cargo carrier, as her ballast tanks will probably be of insufficient capacity to bring her to her deep draft and ballasting by other means might be an unwarranted expense.

In the case of an oil tanker, these conditions may easily be met, as it is practicable to ballast the vessel with water in the cargo tanks to practically full load draft.

Failure of Cargo Oil Pumps

Q.—Discuss the peculiar conditions which may lead to failure in oil cargo pumps.

A.—Robert W. Morrell, in his book "Oil Tankers," has referred to this subject. The following is quoted from his discussion:

"(1) The pumps are required to handle cargo and water ballast alternately, and usually hot oil at that, or equal corrosive gasoline. Provision must be made against corrosion, in the nature of brass liners, fittings, etc., for the liquid ends.

"(2) Internal lubrication must be taken into consideration, especially when pumping gasoline.

"(3) In pumping hot oil, there is a tendency to become gas bound, and air chambers should be provided.

"(4) Convenient means for cleaning out the liquid ends must be provided, such as handhole plates.

"(5) The packing must be capable of withstanding grit and sediment found in some crude oils, and the corrosive effect of gasoline or the alternating of salt water and oil."

"(6) For steam plunger pumps, the steam end must be sufficient to keep the pump moving satisfactorily with low steam pressure due to the shore steam or the drop in pressure in the deck lines in cold weather. The customary ratio of areas of steam to oil pistons is anywhere from 1.1 to 1 to 3 to 1, depending upon the size of the pump, the stroke and the gravity of the oil.

"(7) For motor-driven pumps, there must be every safety precaution to avoid sparks due to contacts, grounds or shorts in the presence of gas generated during discharge of cargo. The importance of this feature cannot be exaggerated.

"(8) The pumps must be highly reliable and of a type which can be handled by a pumpman of ordinary qualifications. The pumps are in operation only a small portion of the vessel's time, but, when needed, they are expected to function efficiently, steadily and without breaking down."

Sub-Punching

Q.—Please define the term "sub-punching."

A.—This term applies to the punching of rivet holes a size or two smaller than that finally required and reaming them out to full size after assembly. This method is of particular value where a high degree of tightness is required, as it secures satisfactory fairness and removes the metal ordinarily damaged by the punch.

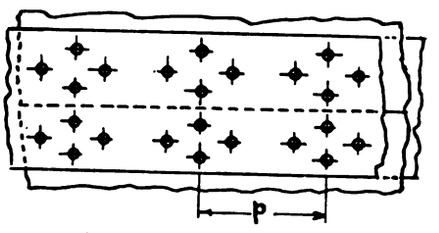
Efficiency of Riveted Joint

Q.—What is the efficiency of the longitudinal riveted joint of a boiler 100 inches diameter built with 7/8-inch plate of 60,000 pounds per square inch tensile strength to carry 180 pounds per square inch steam pressure? Give rule for finding efficiency of a double butt strap joint.

A.—These two questions may be answered as one as follows:

T = thickness of shell in inches = 7/8.
P = steam pressure per square inch = 180.
WP = allowable working pressure in pounds per square inch.
D = mean diameter of shell in inches = 100.
TS = tensile strength of shell plates in pounds per square inch = 60,000.
s = shearing strength of rivets in single shear in pounds per square inch = 44,000.
S = shearing strength of rivets in double shear in pounds per square inch = 88,000.
CS = crushing strength of plates in pounds per square inch = 95,000.
FS = factor of safety of riveted joint (usually about 5 for new work)
d' = diameter of rivets in inches = 1 1/16.
d = diameter of rivet holes in inches = 1 1/8.
a = area of rivet hole in square inches = 0.994.
p = pitch of rivets in inches = 7 1/4 (good practice)
n = number of rivets in shear per pitch.
t = thickness of butt straps in inches.

The longitudinal joint is assumed to have an arrangement of rivets as shown in the sketch.



Longitudinal double butt strap

The A.S.M.E. Code calls for a minimum butt strap thickness of 5/8-inch, when used with 7/8-inch shells.

The Steamboat Inspection Service rule states that for double butt straps the minimum thickness of each is five-eighths of the shell thickness or $0.8754 \times 0.625 = 0.547$ inch $= 35/64$ inch.

Good practice would be to make the inner and outer straps 11/16 inch thick.

Strength of solid plate in pounds $= p \times T \times TS = 7.25 \times 0.875 \times 60{,}000 = 381{,}100$.

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Strength of plate at rivet holes in pounds = (p — d) x T x TS = (7.25 — 1.125) x 0.875 x 60,000 = 321,600.

Strength of rivets in double shear in pounds = n x a x S = 4 x 0.994 x 88,000 = 349,900.

Strength of shell plate in front of rivets in pounds (shell crushing) = n x d x T x CS = 4 x 1.125 x 0.875 x 95,000 = 374,100.

Strength of butt strap in front of rivets (crushing strap) plus strength of rivets in single shear in pounds = (n x d x t x CS) + (n x s x a) = (4 x 1.125 x 0.688 x 95,000) + (4 x 44,000 x 0.994) = 469,100.

Strength of butt strap at inner row of rivets plus strength of rivets in single shear in pounds = (p — d) x t x TS + n x s x a = (7.25 — 1.125) x 6.88 x 60,000 + 4 x 44,000 x 0.994 = 427,800.

For plate efficiency use the least value of the plate strength divided by the strength of the solid plate.

$$\text{Plate efficiency} = \frac{321{,}600 \times 100}{381{,}100} = 84.4 \text{ percent}$$

For rivet efficiency use rivets strength divided by strength of solid plate.

$$\text{Rivet efficiency} = \frac{349{,}900 \times 100}{381{,}100} = 91.8 \text{ percent}$$

$$\text{F. S.} = \frac{\text{TS} \times \text{T} \times \text{least efficiency} \times 2}{\text{P} \times \text{D}} = \frac{60{,}000 \times 0.875 \times 0.844 \times 2}{180 \times 100} = 4.92$$

Abstracts of Articles Translated from the Foreign Press

Increased Economy in Building River Barges

It has been possible by making use of steel of high elasticity to build a Rhine barge of 1,300 tons displacement with great saving in hull weight. The hull weight of such a vessel when built of ordinary shipbuilding steel is about 240 tons. Using steel of 28 tons per square inch elastic limit the hull weight was reduced 25 percent.—*Zeitschrift für Binnenschiffahrt,* June, 1927, 2 pages. (*Schiffbau.*)

Heights of Deck Cargoes

A method is suggested for the determination of heights of deck cargoes of wood. These heights are fixed according to a table taking account of vessel's water plane and block coefficients.—*Hansa,* August 6 and 20, 1927, 2 pages. (*Schiffbau.*)

New Towing Arrangement on Tug Boats

Owing to the many accidents resulting in the capsizing of tow boats it has often been attempted to depart from the usual arrangement of having the tow line hooked in the center line of the tow boat. A short while ago another mishap took place when the American steamer *Republic* was being towed into the docks at Bremerhaven. The marine superintendent for the North German Lloyd, Mr. Oeding, has recently perfected a new towing arrangement which allows the tow line to slide on an arched beam from side to side thus setting up a righting moment instead of a capsizing moment. This arrangement was installed on the tug *Sirius* and proved very successful. Several experiments were carried out, in one case towing the S.S. *George Washington.* In one instance the *Sirius* and a larger and more stable tug boat with the ordinary towing arrangement were tied together. With both vessels running upstream at full speed cutting away from each other, the *Sirius* only took a small list while the other boat had to let go the rope to avoid an excessive list.—*Schiffbau,* September 7, 1927. 1 page.

LETTER TO THE EDITORS

A Proposal to Convert Several Hundred Shipping Board Vessels Into Motorships

TO THE EDITORS:

The growth in the adoption of the motorship abroad presents an alarming menace against the building up of the American merchant marine. Lloyd's report of September 30, 1927, shows that there are under construction 1,163,630 horsepower of motors as compared with 878,869 horsepower of both steam engines and steam turbines. Without question, a large portion of the shipbuilding being carried on by the rest of the world is directed against the commercial marine activities of the American people, principally by the United States Shipping Board. Obviously, this rapid development of motorship tonnage means just one thing—driving American obsolete steamers off the sea with motorships that can be operated at a far lower cost. By the end of 1930 there will be 500 ocean-going motorships, passenger and cargo carriers, competing with our Shipping Board fleet which at that time will have less than 30 motorships. There is a glaring need for a Shipping Board fleet of several hundred motorships, not 10, not 15, and not 30, but several hundred.

How are these obtainable within a reasonable period? Surely not by laying down a new ship construction program which would supply 300 motorships within, say, three years. Such an extensive program is out of the question.

Among the various activities of the Shipping Board over the past several years, there is no project which has met with such success and lack of criticism or opposition as the Diesel conversion program embracing some 23 vessels. No one who has attended the trials of these splendidly reconditioned vessels, equipped with the most modern and economical machinery for both propulsion at sea and handling cargo in port, can fail to admit that these motorships represent a fundamentally sound and forward step toward an enduring American merchant marine. Of the first 12 ships fitted with engines of approximately 3,000 horsepower, the former steam designed speed of about 10 knots has been increased to almost 12 knots. With the 4,000 horsepower engines which are to be fitted in the last 12 conversions recently awarded an average sea speed of 13 knots may reasonably be anticipated. The fuel consumption has been reduced approximately from 35 to 15 tons per day; and it is estimated that the operating cost of the vessels in around-the-world trade has been reduced about $60,000 per year.

It seems conclusive that the only way to supply the lack of motorship tonnage in the Shipping Board fleet is to proceed at once with the conversion of at least 200 more of these obsolete steamers. This work can be accomplished within a period of three years, or at the rate of 70 motorships per year. There would be a return to the Government in reduction of operating costs which would total, upon the completion of the program, probably in excess of $10,000,000 per annum. The saving in operating expenses would alone justify the necessary expenditure of, say, $150,000,000.

But, of greater importance, it would meet the menace of the foreign motorship; it would provide a fleet of economical motorships for sale to private American ship operators; it would prevent the disposal to private American operators of obsolete steam tonnage which will be driven off the seas within a comparatively few years and result in the failure

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of such enterprises; it is dominantly the fundamental essential to supply economical vessels to foster the early success of private maritime ventures during the growing period of our American merchant marine; and that this is the function of the Government under the Merchant Marine Act of 1920 none can gainsay.

Inheriting a fleet of ships built almost exclusively for war purposes, the Shipping Board may be considered to have really little investment in its present tonnage. Among the 700 remaining hulls which have been culled from about 2,000 war-built ships, certainly 200 are well constructed, serviceable ships that, when Dieselized, will meet general requirements of the cargo carrying trade. New, special, fast passenger and cargo vessels could well supplement such a fleet of converted motorships. Shipyards, finding the work of converting single steamers to motorships unattractive, could profitably undertake wholesale conversion work, especially where from 20 to 25 vessels would be subject to the same structural changes for the substitution for existing steam equipment of the same type, make and size of Diesel engine. Both the conversion work and the Diesel engine would cost less than under the recent award of only two Diesel engines of each of several types purchased.

President Coolidge has given evidence that he is ready to support any *reasonable* legislation for assisting our merchant marine. Congress meets in December to consider marine legislation that is in course of preparation. There is a general feeling throughout the country against continued Government operation; so that any program for building new tonnage on an extensive scale is bound to meet with considerable opposition. On the contrary, there would be little opposition to the appropriation of additional money for modernizing the present obsolete steamers. There will undoubtedly be those who will advocate scrapping the existing fleet; building large and fast passenger carriers; building unusually high speed freighters; and all of these projects must stand the Coolidge test of "what is reasonable." The country is ready to support an American merchant marine but it will not take any hasty action on other than a "reasonable" program.

Initial conversion of existing steam tonnage has been successfully accomplished; and it is entirely reasonable to proceed with additional conversion work. This alone will provide the American merchant marine within the next three years with a fleet of several hundred motorships necessary to place American tonnage on a parity, at least in the most important factor, fuel consumption, with foreign competitors.

ENGINEER.

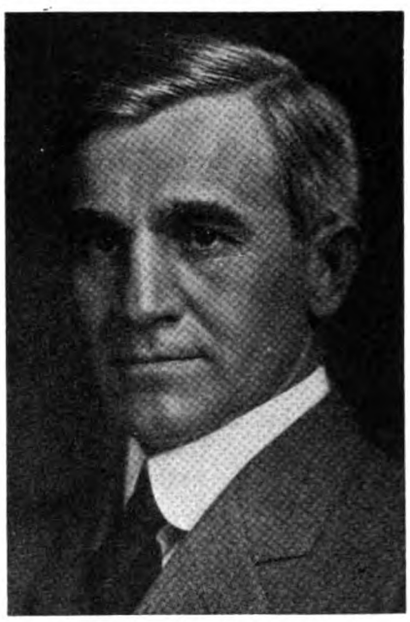
PERSONAL MENTION

E. I. CORNBROOKS has been appointed general manager of the American Brown Boveri Electric Corporation, Camden, N. J., succeeding W. S. Newell, who resigned. In addition, M. W. Torbet has been appointed assistant general manager. Thomas R. Allen, Jr., general superintendent, has had his jurisdiction extended to cover all ships and operating departments of the shipbuilding division.

W. S. NEWELL who for many years had the operation of the Bath Iron Works yard in charge and later was manager of the shipbuilding activities of the American Brown Boveri Electric Corporation (New York Shipbuilding Company), Camden, N. J., has been made president of the recently organized firm to be known as the Bath Iron Works, Inc., Bath, Maine. Associated with Mr. Newell will be A. M. Main as vice-president and naval architect and W. M. Truss, vice-president in charge of sales.

HENRY W. HILL of Buffalo, N. Y., was appointed president at the recent session of the New York State Waterways Association. Other officers appointed include: Peter G. Teneyck of Albany, E. R. Carhart of New York, John J. Hartigan of Troy, Thomas H. Bennett of Oswego and John P. Magill of New York, vice-presidents; Olin J. Stephers of New York, treasurer, and George Clinton, Jr., of Buffalo, secretary.

HOMER L. FERGUSON, president and general manager of the Newport News Shipbuilding and Drydock Company, Newport News, Virginia, was elected president for a term of three years, beginning January 1, 1928, of the Society of Naval Architects and Marine Engineers at the recent annual meeting held in New York. After his graduation from the United States Naval Academy at Annapolis in 1892, Mr. Ferguson studied at the University of Glasgow for three years, after which he became assistant naval constructor at the Columbian Iron Works, Baltimore, Md. From this time until his naval career was concluded in 1905, he filled posts at various shipyards and navy yards with the Bureau of Construction and Repair, finally, during the last two years, being located at the department in Washington. In 1905, Mr. Ferguson became associated with the Newport News Shipbuilding and Drydock Company, Newport News, Va., and served in various capacities until 1915, when he was made president and general manager. His business connections at the present time are widely varied in character. He is a director of the Chesapeake and Ohio Railway Company, the Newport News and Hampton Railway and the Gas and Electric Company. From 1919 to 1920 he was president of the Chamber of Commerce of the United States. He is also a trustee at the present time of the Hampton Normal and Agricultural Institute, a member of the advisory committee of the Massachusetts Institute of Technology, a member of the Academy of Political Science and of the Society of Naval Engineers. Mr. Ferguson is also president of the Council of American Shipbuilders, New York.



Homer L. Ferguson

OBITUARY

WILLIAM J. S. CASWELL, last of an old line of boat builders, died recently at Newport, R. I., at the age of 99.

REAR ADMIRAL JAMES MEREDITH HELM, retired, who had served in Washington as senior member of the commission on the establishment of additional navy yards or naval stations, died recently at Washington, D. C. He was born in Grayville, Ill., in 1855, and was graduated from the United States Naval Academy in 1875.

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The Month's Shipping and Shipbuilding News in Brief

Shipyard, Steamship and Port Activities and Other Notes of Interest in All Branches of the Marine Industries

Specifications Issued for Construction of Two Colliers for Berwind-White Company

PLANS and specifications have been issued by Theodore E. Ferris, naval architect, 30 Church street, New York City, to a number of east coast shipyards for the construction of two colliers for the Berwind-White Coal Mine Company, 1 Broadway, New York. A number of interesting features have been incorporated in the design of machinery on these boats and the work will be followed with great interest by the entire shipbuilding fraternity.

The colliers will have a length of 391 feet, beam of 50 feet and a load draft of 23 feet 6 inches. They will each have a capacity of 6,500 tons deadweight. Among other features, the propelling machinery, which will consist of geared turbines, will operate under the highest boiler pressure ever utilized on any merchant ship—namely, 400 pounds per square inch. Steam will be supplied by Babcock and Wilcox watertube boilers, equipped with Fuller-Lehigh pulverized coal burners. This installation will be the first commercial application of pulverized coal by a private operator. The turbines are designed to develop a maximum of 3,000 shaft horsepower.

It is understood that bids on these two boats will be called in about three weeks' time.

Inquiries Being Made for Construction of 1,000 Horsepower Diesel Tugboat

PLANS and specifications have been issued to Great Lakes shipyards as well as several along the eastern coast by the Great Lakes Dredge and Dock Company, Chicago, Ill., for the construction of a Diesel tugboat. This tugboat will be equipped with a 1,000-horsepower Diesel engine and will be for service on the Great Lakes. No date has been given for the closing of bids. Further details will be available shortly.

Specifications for Auxiliary Diesel Engines to Be Issued by Shipping Board About Dec. 1

IT is understood that specifications are nearing completion covering the auxiliary Diesel engines to be used in the next program of converting Shipping Board vessels to Diesel drive. This work is under the supervision of Captain R. D. Gatewood, manager of the Maintenance and Repair Division of the United States Shipping Board, 45 Broadway, New York. It is believed that the specifications will be issued on or about December 1.

Hudson River Navigation Co. Issues Plans and Specifications for Automobile Carrying Diesel Ships

ACCORDING to information received from C. K. Crosby, general manager of the Hudson River Navigation Company (Hudson River Night Line), Pier 32, North River, New York, plans and specifications for the construction of two Diesel ships have now been issued, although no definite date has as yet been set for the opening of bids. The work is being handled by Henry J. Gielow, Inc., naval architects, New York.

The boats are to have a length of about 300 feet; beam of 50 feet over the guards; depth of hull 16 feet and a speed of 16 knots. They are specially designed for automobile carrying service in the New York-Troy-Albany run.

Theo. D. Wells Issues Plans for 263-Foot Turbo Electric Yacht —Bids Open December 7

IT has been learned that plans and specifications have been issued by Theodore D. Wells, naval architect, 33 Rector street, New York City, for proposals on the construction of a turbo-electric drive pleasure yacht. It is understood that this yacht is to be built to the order of George F. Baker, Jr., New York. Bids for the work will be opened on or about December 7.

The yacht will have a length of 263 feet, a beam of 36 feet and a depth of 18½ feet. She will be equipped with steam turbine electric propelling machinery of 2,600 horsepower. The design calls for a clipper type bow and yacht stern. The yacht will be driven by twin screws.

Bethlehem Shipbuilding Corp. to Build Steamer for Pennsylvania Railroad Company

A CONTRACT for the construction of a 300-foot steamship, to be delivered in nine months' time at Cape Charles, Va., has been awarded to the Quincy, Mass., plant of the Bethlehem Shipbuilding Corporation, Ltd., by the Pennsylvania Railroad Company, 15 North 32nd street, West Philadelphia, Pa.

It is understood that the general characteristics of the proposed steamer will be approximately the same as the steamship *Maryland*. This vessel was equipped with two three-cylinder, triple expansion engines developing about 1,900 indicated horsepower. The price involved was not given out.

Panama S. S. Company Orders Plans Prepared for 500-Foot Liners

THE Panama Steamship Company, New York, has ordered the preparation of plans and specifications for two 500-foot passenger liners from the firm of Cox and Stevens, naval architects, New York. Although no decision has as yet been made on definite details, it is understood that the ships will be fitted with geared turbines, driving twin screws. Steam will be supplied by Babcock and Wilcox watertube boilers at 300 pounds per square inch pressure and 150 degrees superheat. Auxiliaries will be electrically driven and current will be supplied by Diesel engines, connected to generators.

Further details of the work will be available within a short time.

Barge and Carfloat Specifications to Be Sent Out About Dec. 15 by New York Central R.R.

PLANS and specifications are rapidly nearing completion for the construction of four carfloats and 15 barges for the New York Central Railroad. The work is being handled by the marine department of the New York Central Railroad, Produce Exchange building, New York. So far as can be learned at this time, plans will be sent out about December 15 and bids will be received until the first of the year. The size of the floats and barges has not as yet been made available for publication.

Several Oil Tankers to Be Built in the Near Future

ACTIVITY is again being shown in the field of oil tanker construction, it being understood that the Union Oil Company of California, Los Angeles, Cal., will soon send out plans for the construction of a 10,000-ton tanker.

The Standard Oil Company of California, on obtaining permission to continue the operation of the steamship *District of Columbia* with the present machinery, immediately made preparations for the construction, within a short time, of a Diesel electric tanker to be of about 10,000 tons, in which the machinery purchased for the conversion work will be used.

It is also understood that the Sun Oil Company, Philadelphia, Pa., is contemplating the construction of another tanker to be of about 10,000 tons capacity.

The Cities Service Company, New York, is again reviving its plan to build a new tanker, which will be about 13,000 tons carrying capacity.

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New England S.S. Co. Places Order for Steamer with Bethlehem Shipbuilding Corp.

A CONTRACT for the construction of a new steamer has been awarded by the New England Steamship Company, Newport, R. I., to the Bethlehem Shipbuilding Corporation, Ltd., Bethlehem, Pa., at a price of $382,400 and a delivery time of 7½ months.

It is understood that the new steamer will follow the same general lines as the *Nobska*, the last vessel added to the fleet. In this case the ship had an overall length 210 feet; length between perpendiculars 202 feet; breadth, molded, 36 feet; depth, molded 14 feet 6 inches; maximum draft 10 feet; gross tonnage 1,082 and passenger capacity 2,000. The propelling machinery consisted of a four-cylinder, triple expansion engine, 16 inches, 26 inches, 30 inches and 30 inches by 24 inches stroke and two Babcock and Wilcox boilers, burning coal.

The new vessel will be constructed almost entirely of steel and is to be practically fireproof, but will, nevertheless, be equipped throughout with automatic sprinklers and have a complete thermostatic fire alarm system.

Henry J. Gielow, Inc., Working on Plans for Large Yachts

A NUMBER of orders for the design of new pleasure yachts, propelled by various types of machinery, are now under way at the offices of Henry J. Gielow, Inc., 25 West 43rd street, New York. The list of work being carried out by this firm, which will materialize in a definite way within a comparatively short time includes:

One 115-foot yacht to be propelled by Diesel engines;

One 165-foot yacht to be equipped with Diesel engines;

One 190-foot three-masted schooner in which auxiliary Diesel engines will be installed;

One 240-foot yacht to be propelled by geared turbines.

One 310-foot yacht to be propelled by turbo-electric machinery;

One 340-foot yacht to be equipped with Diesel engines.

Of these, it is understood that within the next few days, the 310-foot turbo-electric yacht contract will be placed, although no information is as yet available on the definite date of the award.

Long Island Railroad Plans for Diesel Electric Tugboat Nearing Completion

INFORMATION has been received that the Long Island Railroad Company, New York, has ordered the preparation of plans and specifications for the construction of a new Diesel-electric tugboat which will be similar to the latest one placed in service. Eads Johnson, naval architect, 115 Broadway, New York, is handling the work.

It is understood that the specifications are now practically completed and will be issued shortly to shipyards for bids, at which time further information will be made available for publication.

W. S. Newell Heads New Organization of Bath Iron Works Corporation

ONE of the most interesting and encouraging events that has occurred in the field of shipbuilding for some time, is the reopening of the Bath Iron Works, Bath, Maine, under the name of the Bath Iron Works, Inc. The president and general manager of the new undertaking is W. S. Newell, who for many years had the operation of the Bath yard in charge and later was manager of the shipbuilding activities of the American Brown Boveri Electric Corporation (New York Shipbuilding Company) Camden, N. J. With Mr. Newell will be A. M. Main, as vice-president and naval architect, a man who has an enviable reputation in the shipbuilding field. W. M. Truss is vice-president of the new organization in charge of sales. The plant and equipment, which still remain at Bath, are in excellent condition and it is understood that new machinery designed for production work, both in the wood-work department and in the hull department, will be installed, so that the yard will be capable of meeting the requirements of construction of vessels up to 450 feet in length. The plant will actually be unique among the shipyards of this country since it will devote its main attention to the construction of hulls, joiner work and the like, utilizing any special type of machinery that may be specified for a given job. It is not intended to operate a machine plant at the yard, but to purchase and install propelling and auxiliary equipment where it can be done under the most advantageous terms, and to meet any given requirements.

It is believed that within the near future a number of large pleasure yacht orders will be placed with the yard and operation will be actively commenced within a very short time. Further information in connection with the opening of the yard, its facilities under the new management and contracts placed, will appear in *Marine Engineering and Shipping Age* from time to time.

Bath Iron Works Awarded Contract to Build 240-Foot Diesel Yacht

A CONTRACT has been placed with the Bath Iron Works, Inc., Bath, Me., for the construction of a Diesel yacht by the firm of Henry J. Gielow, Inc., New York. This yacht will have a length overall of 240 feet, length on the waterline 220 feet, beam 36 feet and draft 14 feet 6 inches. The yacht will be given classification with Lloyd's Register of Shipping. The main propelling machinery will consist of two 1,500-horsepower Bessemer Diesel engines, which will give the boat a speed of 16 knots.

The yacht will be entirely of steel construction, designed with a straight bow and yacht stern. Accommodations include six staterooms and six baths. The owner's suite, consisting of stateroom, sitting room and bath, will be located on the main deck. The dining saloon, living saloon and smoking room will also be situated on the main deck.

The yacht is to be delivered to the owners on August 1, 1928.

Great Lakes Engineering Works to Build Largest Automobile Ferry Steamer on Lakes

A CONTRACT for the construction of the largest steel automobile and ferry steamer on the inland waters of America, has been awarded to the Great Lakes Engineering Works, River Rouge, Michigan, by the Detroit and Windsor Ferry Company, Detroit, Mich. The ferry, which was designed by Frank E. Kirby, naval architect of Detroit and New York, will have a carrying capacity of 75 automobiles and will be placed in service between Detroit and Windsor in April of next year. She will be 157 feet long, 56 feet beam and 17 feet 6 inches deep.

Morse Yard to Carry Out General Overhaul of Liner George Washington

THE main contract for general overhaul and repairs to the United States Lines' steamship *George Washington*, was placed last month with the Morse Drydock and Repair Company, Brooklyn, New York. This contract includes the general overhaul of the vessel in both hull and machinery departments. The following bids were submitted covering the work:

Name	Price
Newport News Shipbuilding and Drydock Company	$118,865
Morse Drydock and Repair Company	131,918
W. and A. Fletcher Company	137,000
Bethlehem Shipbuilding Corporation, Ltd.	150,600
Tietjen and Lang Drydock Company	158,309

Matson Liner Maui to Be Reconditioned and Refitted

THE 9,801 gross-ton liner *Maui* of the Matson Navigation Company, San Francisco, California, has been withdrawn from service and is now at the yards of the Bethlehem Shipbuilding Corporation, Ltd., San Francisco, Cal., undergoing overhauling and reconditioning. She will be out of commission until February 1.

All passenger accommodations of the liner will be refurnished and the staterooms will be equipped with running hot and cold water. The smoking room of the *Maui* is being enlarged to twice its former size and will be used as a smoking lounge for the accommodation of both men and women passengers. The galley and pantry of the liner is to be relocated adjacent to the dining salon to facilitate meal service involving a complete rearrangement of the main deck.

When the *Matsonia* arrives at San Francisco on her next voyage from the islands, she will be withdrawn from service for a period of two months, during which time similar changes and improvements will be made.

Shipping Board Orders Anchors from Baldt Anchor Co.

THE United States Shipping Board has placed a contract with the Baldt Anchor Chain and Forge Corporation, Sixth and Butler streets, Chester, Pennsylvania, for the construction of 15 anchors from 7,600 to 9,000 pounds each and 30 shots of 2¼-inch chain. The price involved was not given out.

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New Section to Be Added to Equipment of Maryland Drydock Co.

THE Maryland Drydock Company of Baltimore, Md., is about to add another floating drydock to its repair yard equipment. The present drydock equipment consists of a 9,000-ton floating drydock of the Crandall sectional type. It will substantially be a duplicate consisting of a five-section dock which has been located at Jacksonville for some years and to which one new section will be added. The Jacksonville dock was built from the same plans as the present drydock, but only five of the six sections were built.

Plans for the new section are being furnished by the original designers of the dock, the Crandall Engineering Company of Boston, Mass. These drydocks are of a patented type which retains all the self-docking advantages of a sectional dock while also retaining all of the longitudinal strength advantage of a solid dock.

Plans Being Prepared by J. H. Wells for Two Diesel Yachts

INFORMATION has been received that plans and specifications are now nearing completion in the office of John H. Wells, naval architect, 11 East 44th street, New York, for the construction of two Diesel yachts. One of these will have a length of 135 feet and the other a length of 125 feet. It is expected that work will be completed on the plans in about three weeks time, when the specifications will be sent out for bids. Further details will be available at that time.

Kensington Shipyard Sold

AGREEMENTS were executed recently by the William Cramp and Sons Ship and Engine Building Company, Philadelphia, Pa., for the sale of the Kensington drydocks and repair yard property, at Beach and Palmer streets. The identity of the purchaser was not disclosed, but it is understood the yard will be operated by a company composed of men thoroughly familiar with the class of work which has been carried on there for so many years.

Assembling department of Winton Engine Company

Winton Business Reaches New High Peak

FOR the past six months orders for engines of all kinds, including auxiliaries, such as generator sets, pump sets and air compressor sets, have been booked in unprecedented volume by the Winton Engine Company, Cleveland, O. The result is that the business now in process at this plant sets a new high peak for this particular company.

Present business under way totals more than $2,000,000. The line includes both gasoline and Diesel engines, ranging from 50 to 1,500 horsepower, for yachts, workboats, rail cars, moving picture lighting sets, and many other purposes. The illustrations on this page show two views of the assembling department. Here are assembled all of the units built, from 7½ kilowatt generator sets to 1,500 horsepower Diesels.

View in Winton shops, showing variety of work under construction

Testimonial Dinner to Admiral Plunkett

ON February 15 next Rear Admiral Plunkett, commandant of the Third Naval District and of the New York Navy Yard, will retire from the Navy because of the age limit.

On that evening a testimonial dinner will be held at the Waldorf-Astoria, New York city, which will be sponsored by a number of organizations and by individuals prominent in financial and industrial circles, including, among others, the following:

James A. Farrell, president of the United States Steel Corporation; L. F. Loree, chairman of the Association of Railway Executives; William Green, president of the American Federation of Labor; William H. Todd, president of the Todd Shipyards Corporation; William L. DeBost, president of the New York Chamber of Commerce; Brig. Gen. Palmer E. Pierce of the Standard Oil Company; Hon. Lewis Nixon; R. A. C. Smith; Maj. Gen. Charles P. Summerall, Chief of Staff, U. S. Army; Maj. Gen. William N. Haskell, commanding general, N. Y. National Guard; Maj. Gen. J. G. Harbord, president, Radio Corporation of America and Brig. Gen Cornelius Vanderbilt.

Colonel Edward A. Simmons, 30 Church street, New York City, is temporary chairman.

Advantage will be taken of the occasion to boost the American merchant marine. The speakers will be men of national prominence and what they say will be widely broadcasted.

Navy Department Awards Scout Cruiser Chain Contract

THE Navy Department, Washington, D. C., has awarded a contract to the National Malleable and Steel Castings Company, Cleveland, Ohio, for the construction of 2¾-inch cast steel chain to be used on five of the light cruisers built by the Bethlehem Shipbuilding Corporation, Ltd., Bethlehem, Pa.; American Brown Boveri Electric Corporation, Camden, N. J., and the Newport News Shipbuilding and Drydock Company, Newport News, Va.

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TRADE PUBLICATIONS

ELECTRIC WELDERS.—Details of the Seneca electric arc welder, with illustrations showing a number of its applications in repair work, is the subject of a bulletin issued by the Seneca Electric Welder Corporation, Detroit, Mich.

DIRECT CONNECTED TURBINE GENERATOR UNITS.—The Westinghouse Electric and Manufacturing Company, South Philadelphia Works, has recently released an instructive leaflet describing direct connected turbine generator units in capacities of 5, 7½, 10 and 15 kilowatts. These units are for 125 and 250 volts direct current operation. Included in the leaflet are a number of photographs showing the construction and operation of these units.

THE TERRY TURBINE.—A bulletin containing a short history of the Terry Steam Turbine Company, Hartford, Conn., the application of the Terry wheel turbine, its advantages, principle of operation and detailed description of its parts, including the various types of governors, has recently been issued. In addition to the above, the bulletin also contains a description of the turbine for high steam pressures, the general design features of Terry turbo-generator units, pump drives, blower drives, pulverizer drives, Terry gears and Terry shaft couplings.

DE LAVAL EQUIPMENT.—Centrifugal blowers and compressors, together with pumps, turbines and speed reducers as used for special types of work, are described in a bulletin now being distributed by the De Laval Steam Turbine Company, Trenton, N. J. Centrifugal blowers and compressors, built by this company, are provided with various numbers of stages, ranging from single stage blowers to multistage compressors capable of supplying air at 100 pounds per square inch pressure. De Laval centrifugal blowers and compressors are driven by De Laval steam turbines or by electric motors. Speed increasing gears are sometimes used in order to utilize standard speed motors.

THE FOSTER ECONOMIZER.—The Foster economizer for recovering waste heat from boiler flue gases is described in a third descriptive catalogue on this subject which has been sent out by the Foster Wheeler Corporation, New York. At the present time there are approximately 300 installations of the economizer in operation, amounting to about 600,000 boiler horsepower so equipped. The present work includes a general survey of the developments in economizer practice, an outline of the changes in the design of boilers brought about by these developments and a detailed description of the construction of the pressure parts and housing of the Foster economizer. There are also included illustrations of typical arrangements effected by the compactness of this apparatus, as well as test data showing the performance of some of the economizers in service.

WEAR ON DIESEL ENGINE PARTS.—In order to answer a question that is often asked by Diesel engine users and prospective buyers of Diesel engines on the amount of wear on the various parts of this type engine, the Busch-Sulzer Brothers-Diesel Engine Company, St. Louis, Mo., has compiled a record of the wear on 100 Type B Busch-Sulzer Diesel engines in use between the years 1914 and 1924. In preparing this record, a questionnaire was sent to every purchaser of engines (total 215) of this type, requesting records of wear and replacements. One hundred and three replies were received, but three of these covered engines installed in 1925 and 1926; so these three were omitted from the tabulation because of the short period of service. In the present booklet, illustrations are given of numerous Diesel engine installations of the various sizes on which the records were reported. The results obtained from the report have been compiled on a chart, which is the most complete work, so far as is known, ever prepared by any Diesel engine builder. The information contained on the chart includes: The engine number, engine brake horsepower, year installed, hours operated since installation, average hours between stops, average load in kilowatts, peak load in kilowatts, frequency of general overhaul in months, frequency of routine inspection and adjustment in days, period of removing heads and pistons. Under the main heading of wear and replacement of parts, the tabulation includes sections covering piston pin bearings, crankpin bearings, main bearings, cylinder liners, cylinder heads, pistons, piston rings and compressor valves. The composite record for the various items is as follows: Cylinder head, one out of four replaced in 5.5 years; liners, average life 6.88 years; pistons, one out of four replaced in 7.8 years; piston pin bearings, average wear per year 0.00094 inch; crankpin bearings, average wear per year 0.002 inch; main bearings, average wear per year 0.0015 inch. The booklet concludes with illustrations of various typical land and marine Diesels.

BUSINESS NOTES

W. H. McMillan's Sons, manufacturer of tackle blocks, has moved the New York office and salesroom from 153 South street to 49 South street.

The Falk Corporation, Milwaukee, Wis., announces that arrangements have been made with William Kennedy and Sons, Ltd., Owen Sound, Ontario, whereby this company is to manufacture and sell Falk continuous tooth herringbone gears, Falk herringbone speed reducers and Falk flexible couplings in Canada.

The American-LaFrance Fire Engine Company, Inc., of Elmira, N. Y., has acquired the assets and good will of the Foamite-Childs Corporation of Utica, N. Y., and the business of the two companies will be combined under a single corporate identity. The name of the company will be the American-LaFrance and Foamite Corporation.

S. F. Bowser & Company, Inc., Fort Wayne, Ind., announce the establishment of a marine department, specializing in Bowser equipment for the storage, handling, pumping and measurement of oils, paints and other liquids, also in oil filters, oiling systems, pressure grease lubrication, mechanical force-feed lubricators, lubricating oil pumps and accessories in order to better serve their customers in the marine field. The headquarters are at 67 West 44th street, New York.

Marine Societies

America

American Marine Association. 30 Church St., New York. President—Col. E. A. Simmons.

American Marine Standards Committee. Chairman, Colonel E. A. Simmons. Secretary, A. V. Bouillon, Division of Simplified Practice, Department of Commerce, Washington, D. C.

American Society of Marine Designers. Secretary—B. G. Barnes, 202 Kendrick Ave., Quincy, Mass.

American Society of Marine Engineers. 605 Market St., San Francisco, Calif. President—Henry F. Gelhaus. Secretary—Wm. H. Thille.

American Society of Naval Engineers. Navy Department, Washington, D. C. Secretary-Treasurer—Commander H. B. Hird, U. S. N., Bureau of Engineering, Navy Department, Washington, D. C.

American Steamship Owners' Association. 11 Broadway, New York. President—H. B. Walker.

Atlantic Coast Shipbuilders' Association. 1600 Walnut Street, Philadelphia, Pa. Secretary—C. S. King.

Council of American Shipbuilders, Inc., 50 Broadway, New York. President—Homer L. Ferguson. Secretary-Treasurer—Henry C. Hunter.

Jersey Marine Club, 4th and River streets, Hoboken, N. J. President—Col. Bartlett.

Lake Carriers' Association. President—J. S. Ashley. Secretary—George A. Marr, Rockefeller Building, Cleveland, O.

National Association of Engine and Boat Manufacturers. 29 West 39th Street, New York City. Secretary—Ira Hand.

National Association of Masters, Mates and Pilots. National Secretary—M. D. Tenniswood, 308 Vine St., Camden, N. J.

National Marine Engineers' Beneficial Association. Headquarters, 311-315 Machinists Building. Washington, D. C. President—Wm. F. Yates. Secretary—Albert L. Jones.

National Merchant Marine Association. Munsey Bldg., Washington, D. C. President—Hon. J. E. Ransdell.

Neptune Association. 21 Pearl St., New York City. Secretary-Treasurer—Captain John F. Milliken.

New York and New Jersey Dry Dock Association, 111 Broadway, New York. President—Jonathan Moore.

Ocean Association of Marine Engineers. 15 Whitehall St., New York. Secretary—Bert L. Todd.

Port of New York Authority. 75 West Street, New York. Chairman—George S. Silzer. Secretary—Wilson J. Vance.

Society of Naval Architects and Marine Engineers. 29 West 39th Street, New York. Secretary and Treasurer—Daniel H. Cox.

The Maritime Association of the Port of New York. 78 Broad St., New York City. President—John Dowd. Secretary—John F. Manning.

The New York Tow Boat Exchange. 11 Moore St., New York. Manager—Langdon W. Smith.

The Propeller Club of the Port of New York. President—Harry W. Parsons, 111 Broadway, New York. Secretary—W. Z. Gardner, 136 Liberty street, New York.

United States Naval Institute. Naval Academy, Annapolis, Md. Secretary and Treasurer—Captain H. A. Baldridge, U. S. N.

United States Ship Operators' Association. 149 Broadway, New York. President—Winchester Noyes.

Canada

Grand Council N. A. of M. E. of Canada. Grand Secretary-Treasurer—W. A. MacDonald, 62 Albert St., Halifax, N. S.

Great Britain

Institute of Marine Engineers, Incorporated. 85/88 The Minories, London, E.1.

Institution of Engineers and Shipbuilders in Scotland. 39 Elmbank Crescent, Glasgow.

Institution of Naval Architects. 5 Adelphi Terrace, London, W. C.

North East Coast Institution of Engineers and Shipbuilders. Bolbec Hall, Westgate Road, Newcastle-on-Tyne.

France

Association Technique Maritime et Aéronautique. Secrétariat Général—7, rue de Madrid, Paris (8e).

Italy

Collegio Degli Ingegneri Naval e Meccanici in Italia.

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